

NONPARAMETRIC MULTIVARIANT ATTRIBUTE  
RETRIEVAL UTILITY SYSTEM

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## PREFACE

This study is concerned with the development of a file screening method which recognizes and permits the existence of individual user differences during the screening process. The proposed procedure utilizes the decision-maker's order of attribute importance within the various file entities by the use of a scheme of connecting mathematically relatable weights to each attribute of the set of file entities. Determination is made of a group of methods that will function in a complementary fashion to quantify, order, weight, and calculate the attribute match score for each of the set of entities.

This type of approach has been used to avoid the fairly rigorous coding and/or key word structures usually found in an information retrieval system. Individual user preferences can make a significant difference in the level of ultimate satisfaction with the results from the retrieval activity. Rigorous structures presuppose standard preferences and values which do not exist within a set of possible users or even uses of a retrieval system.

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## LIST OF SYMBOLS

<i>alpha</i>	- Weight sensitivity factor
$\alpha$	- Symbol for weight sensitivity factor
APPL	- Table of applicant attribute values
ATTR	- General term representing the identification elements (as name, address, etc.) of an item being retrieved
BETBAD	- Temporary table of attribute designators wherein the item under consideration for retrieval is better or poorer than required
BSTPOR	- A pushdown matrix used to record the instances of better and poorer attribute strata values of the ten best job applicants
<i>code</i>	- An identification code used to keep together all input records which describe a single job opening
<i>dsex</i>	- A yes/no designator in response to the question, "Can work be done by both sexes?"
$\epsilon$	- A vector containing only the digit one; as $\epsilon(15)$ represents a fifteen element vector containing the digit one in each position
$\bar{\epsilon}$	- A vector containing only the digit zero; as $\bar{\epsilon}(6)$ represents a six element vector containing the digit zero in each position

<i>E</i>	- A matrix containing only the digit one; as <i>E</i> (9) represents a matrix of nine cells containing the digit one in each position
<i>Ē</i>	- A matrix containing only the digit zero; as <i>Ē</i> (10) represents a matrix of ten cells containing the digit zero in each position
ENTITY	- Table of file attribute values
ENTRY	- A convenient vector for entering the requirements for a successful entity match
<i>extra</i>	- An accumulator for determining the quantity of situations wherein applicant attributes exceed match requirements
<i>i</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>ii</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>iquit</i>	- An end-of-file signal used to terminate the retrieval processing
<i>j</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>jj</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>jk</i>	- A temporary index for accessing elements in a vector or in a matrix
JOB	- A vector containing the required attribute strata values

<i>jobcd</i>	- An identification code used to keep together all input records which describe a single job opening
<i>k</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>l</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>less</i>	- An accumulator for determining the quantity of situations wherein applicant attributes fail to meet match requirements
<i>ll</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>ln</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>m</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>mn</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>mm</i>	- A general term representing the quantity of entities to be held in the pushdown storage matrices
<i>n</i>	- A temporary index for accessing elements in a vector or in a matrix
<i>na</i>	- Number of job applicants
NAME	- A table containing applicant names
ORDER	- A vector containing the attribute item numbers in their sequence of importance

<i>psex</i>	- A designator indicating the preferred sex for a job incumbent
<i>rank</i>	- An accumulator used to determine the quantity of attributes being used in a retrieval exercise
RESULT	- A pushdown vector used to store the scores of the ten best applicants
<i>rsex</i>	- A designator indicating the required sex for a job incumbant
SAVSEX	- A pushdown vector used to store the sex of the ten best applicants
<i>score</i>	- An accumulator to determine the weighted total of an entity's attributes that have been found to be acceptable
SEX	- A vector containing applicant sex designations
SOCS	- A vector containing applicant social security numbers
STRATA	- A vector containing the required attribute strata values
TBL	- A pushdown matrix used to store retrieval information concerning the ten best applicants
WEIGHT	- A vector of exponential weights
<i>wgt</i>	- The complement of the weight sensitivity factor

WHO	- A pushdown matrix used to store the names of the ten best applicants
•	- (• not .) symbol representing the operation of multiplication
' '	- Symbol representing a blank character
' ' • ε(10)	- A vector of ten blank characters
*	- Symbol representing the operation of exponentiation (raising to a power)
:	- Symbol representing a value comparison; as a : b represents a check to ascertain whether a is less than, equal to, or greater than b
+	- Symbol representing the operation of addition
-	- Symbol representing the operation of subtraction
/	- Symbol representing the operation of division
←	- Symbol representing replacement; as a ← b represents replacing the value of a with the value of b
→	- Symbol representing a transfer of control; as → AR15 represents a transfer to step AR15. In a like manner, a : b < → AR7 represents a transfer to step AR7 when the value of a is less than the value of b
subscripts	- Raised trailing index (as $BSTPOR^i$ ) represents the vector element or matrix row - Lowered trailing index (as $BSTPOR_j$ ) represents the matrix column

- Raised leading index (as  $k_{\text{BSTPOR}}$ ) represents the matrix plane

## CHAPTER I

### PROBLEM DEFINITION

#### Introduction

The digital computer, which has been a relatively commonplace device for only about a decade and a half, is alternately praised and cursed. To the uninitiated, the computer is held to be a Merlin capable of bestowing instantaneous wisdom and success upon anyone within its circle of disciples. To those having an understanding of the elements operating behind the blinking lights, spinning wheels and vast quantities of printed paper, there is the sober realization that while a computer is fast, it is no more able than its user - the one who decides precisely what will be done in any given set of circumstances.

The economy of the United States is slowly recovering from a serious recession. While many of the effects of this recession have been painful, it has provided the opportunity for an evaluation of goals, plans, and the specific methods of their accomplishment. All should ultimately benefit from these effects of the economic pause. The computer and the methods of its use have been included in this process of evaluation. This was pointed out as follows in a recent issue of Business Week (1):



Under the lash of the economic downturn in 1970, computer users have been reappraising their investment. In thousands of companies, data-processing departments have felt the pinch as budgetary brakes took hold. The computer, despite its promise as a cost-cutter and a management necessity, stands revealed as an expense just as subject to budgetary limits as are new office space or machine tools.

The Business Week (1) article makes a special effort to point out that the computer has been extraordinarily useful.

This is illustrated as the article continues:

There are more than enough places, though, where computers have more than earned their keep. Airlines, committed to split-second scheduling of high-priced equipment, could not effectively allocate their mobile resources and crews without them. In engineering and science, computers have been mind-expanders of inestimable value. Where computers have really paid off in the commercial world is in the countless functional and operational jobs of keeping track of fine details in production, orders, and payments. Here the computer itself has become a production machine. Huge data centers, such as those of the Social Security Administration, and large banks, such as New York's First National City Bank, are set up more according to the rules of industrial engineering than to those of office routine. In the past few years, virtually all the obvious jobs have been computerized, from running payrolls to simulating the performance of a new jet engine or an electrical network. With some 70,000 computers already at work in the U. S., the question in most applications is no longer whether to use a computer, but what sort of system to use. Arguments still rage about the merits of supercomputers, which offer economies of scale and integrated data bases, compared with those of smaller systems that are dedicated to single functions and avoid bureaucratic tangles. There is also a harder-nosed attitude toward costs.

One of the primary functions of computers is to aid in the process of decision-making. Management Information Systems (MIS), is the general name which has been given to this function of providing the necessary information to aid

managers in making timely and appropriate decisions. While some items of data such as sales figures or labor costs readily lend themselves to processing to become meaningful information, a major segment of the potential data base is not sufficiently quantified. This problem was well stated by Arlene Hershman (2):

A major cause of frustration is the uselessness of much computerized information. Overdetailed records are spewed forth by 600-line-a-minute print-out machines, inundating management with all the information it does not need to make a decision. First National City Bank of New York, for example, can point with pride to the many achievements of its EDP operation in creating new revenues, attracting new customers and improving budgeting. But in the area of MIS, the record is something else again. Vice President Robert Owen, who was recently assigned to whip the bank's MIS operation into shape, pinpoints the trouble: 'The chief executive knows that the problems of the business are hidden somewhere in that pile of print, but he cannot find them.'

One of the solutions to the problem of extremism in detail is the development of sophisticated software applications wherein the decision-maker can conversationally interact with the computer and withdraw or retrieve only those parcels of data which are informative and pertinent to the problem at hand. While efforts are continuing in the area of software development, specialist rather than more generalist results occur. Many fine packages exist which can be utilized for specific tasks such as the analysis of sales, investment portfolios and a myriad of other selected quantitative subjects.

## Statement of Problem

A key issue is the difficulty for computers to make meaningful comparisons between non-numeric attributes of entities being considered for retrieval. A great deal of current research is directed towards the retrieval problem. Such a conclusion is reached by noting the purpose of much of the federally sponsored information retrieval research as reported by the Science Information Exchange of the Smithsonian Institution. The Science Information Exchange is the agency charged with the responsibility of maintaining a national collection of current research information and serving as a comprehensive single source for on-going research information in all sciences. This conclusion is also firmned by a review of the abstracts of research which are reported quarterly in the Transactions of the American Institute of Industrial Engineering. A close look at the nature of the reported endeavors indicates that primary effort involves retrieval procedures for selecting bibliographical, article and abstract types of information. Many proprietary software packages reported in Industrial Engineering, Software Age, Datamation and Data Product News are of this type. While quantitative or semi-quantitative methods are used in most of these retrieval procedures, little effort appears to have been expended towards quantifying the data itself. At this point in the evolution of computer utilization methods, data quantification appears to

be a prerequisite for rapid, successful information-from-data processing.

Another troublesome problem exists when constructing and using an information retrieval system. Fairly rigorous coding and/or key word structures are usually required. Individual differences or preferences can make a significant difference in the level of user satisfaction with the results from the retrieval activity. Rigorous structures presuppose standard preferences and values which do not exist within a set of possible users or even uses of a retrieval system.

The purpose of this dissertation is to propose a file screening method which recognizes and permits the existence of individual user differences during the screening process. The basic screening activity will consist of checking each record or entity contained in the file by noting the acceptability of the various data items or attributes within the record. To accomodate the existence of individual preferences, the proposed method will utilize the decision-maker's (user) order of attribute importance within the various file entities. The procedure for handling the sequence of attribute importance must be flexible rather than rigid, since the decision-maker frequently has different objectives during separate searches of a data file.

Successful accomodation of a flexible, importance ordering procedure requires the use of a scheme of connecting mathematically relatable weights to each attribute of

the set of file entities during the retrieval activity. In addition, a method is necessary that will provide for the quantification of normally qualitative data to permit the calculation of an entity match rank or score for each of the file entities receiving retrieval consideration. This is necessary because most human selection between alternatives is accomplished through some type of ranking procedure. Resultant match scores generated by the proposed method will provide a basis for the ranking of alternatives.

The scope of this dissertation is to determine a group of methods that will function in a complementary fashion to quantify, order, weight and calculate the attribute match score for each of a set of entities. The overall procedure is to function by evaluating the suitability of the attributes of the several entities according to the sequence desired by the using decision-maker.

Part of the research effort will be directed toward verification of the proposed screening method. Testing will be accomplished by using it with a previously developed set of attributes to be considered when matching the abilities of handicapped persons and job position requirements. The resultant procedure will be applicable, with minor change, to other retrieval tasks.

#### Literature Search

Over the years various schemes have been proposed which are capable of affixing a quantitative value to qualitative

data. Churchman (3) notes:

The necessary relative weights might be assigned in terms of dollar amounts merely by putting a certain dollar sign on every objective. This has the apparent advantages of a measure that is readily understandable, objective, and universally used. The difficulties in the use of monetary scales are also apparent. Many objectives cannot be measured in terms of dollars. In many cases we value differently two things which can be obtained at the same cost. In other cases costs are very difficult to assign.

Churchman (4) has also developed a method for estimating the relative values of a set of objectives, including intangibles, along a common scale. The proposed procedure utilizing four different outcomes is as follows:

1. Rank the four outcomes in order of importance. Let  $O_1$  represent the outcome that is judged to be the most important,  $O_2$  the next,  $O_3$  the next, and  $O_4$  the last.

2. Tentatively assign the value 1.00 to the most valued outcome and assign values that initially seem to reflect their relative values to the others. For example, the evaluator might assign 1.00, 0.80, 0.50, and 0.30 to  $O_1$ ,  $O_2$ ,  $O_3$ , and  $O_4$  respectively. Call these tentative values  $v_1$ ,  $v_2$ ,  $v_3$ , and  $v_4$  respectively. These are to be considered as first estimates of the true values  $V_1$ ,  $V_2$ ,  $V_3$ , and  $V_4$ .

3. Now make the following comparison:  
 $O_1$  versus ( $O_2$ -and- $O_3$ -and- $O_4$ )  
i.e., if the evaluator had the choice of obtaining  $O_1$  or the combination of  $O_2$ ,  $O_3$ , and  $O_4$ , which would he select? Suppose he asserts that  $O_1$  is preferable. Then the value of  $v_1$  should be adjusted so that

$$v_1 > v_2 + v_3 + v_4$$

For example:  $v_1 = 2.00$ ,  $v_2 = 0.80$ ,  $v_3 = 0.50$ , and  $v_4 = 0.30$ . Note that the values of  $O_2$ ,  $O_3$ , and  $O_4$  have been retained.

4. Now compare  $O_2$  versus  $O_3$ -and- $O_4$ . Suppose  $O_3$ -and- $O_4$  are preferred. Then further adjustment of the values is necessary. For example:  $v_1 =$

2.00,  $v_2 = 0.70$ ,  $v_3 = 0.50$ , and  $v_4 = 0.30$ . Now each value is consistent with all the evaluations.

5. In this case, the evaluations are completed. It may be convenient, however, to normalize these values by dividing each by  $\sum v_j$ , giving  $V_j$ .

The resulting  $V_j$  values yield what could be considered the relative utility the decision-maker held for the several outcomes.

Another method for determining an individual's utility scale for outcomes was developed by von Neumann and Morgenstern (5). It is known as the standard gamble method. In many respects this method is similar to that of Churchman noted previously. Both yield scalar values for each outcome that are mathematically relatable. It is to be noted that both methods break down if one or more of the possible outcomes is overwhelmingly bad, such as bankruptcy.

Various methods exist wherein points are assigned to factors and levels in such applications as job evaluation and plant site selection. Reed (6) has proposed an elaborate method for point assignments to those factors which are considered to be significant in plant site selections, but, for which meaningful cost figures cannot be determined. He introduces his method by stating:

As with any situation requiring subjective evaluation, it is necessary to design an evaluation system whereby each factor is assigned a proportional value relative to all other factors under consideration, while at the same time providing a means whereby a value for each factor may be assigned to each location depending upon the degree or quality of that factor existing at the particular location under consideration.

Reed's method utilizes nine fairly complex and time consuming steps. However, when the procedure is followed, a series of mathematically relatable values result. The method is time consuming, especially when many potential sites are being considered.

A variation of Reed's method has been proposed by Hicks and Kumtha (7). Their method incorporates the development of factor weights based on the standard deviation of all factors. Points are assigned each factor for each location on the basis of the factor weight and the dispersion of that location's factor cost from the best location's (for that factor) factor cost. Site selection is based on the lowest number of points.

All noted methods, while producing mathematically relatable factor weights, suffer from the twin faults of not being readily applicable in a computer and requiring an extraordinary amount of effort - especially when a large number of potential outcomes exist. A method is needed that will rapidly sift through a large number of possible outcomes and select a few which have a high probability of being suitable. Final, fairly precise selection might be made using one of the noted methods of ranking alternatives.



## CHAPTER II

### MODEL DEVELOPMENT

Attribute weights must be readily applied, to make it easier for users to apply the procedure. From a user standpoint, attribute weighting which is automatic or nearly automatic within the retrieval sequence is a desirable goal. A recursively applied procedure, unless quite complex, requires few programming steps and little computer effort. A simple weighting, such as 1, 2, 3, . . . ,  $n$ , may be useful, but the weights are not readily mathematically relatable. While they could be summed and normalized, nothing exists to indicate that the alternate weights of 1, 5, 7, 25, . . . ,  $n$ , could not also be used. In other words, this simple scheme of attribute weighting is essentially meaningless.

A forecasting technique, the weighted moving average, is somewhat feasible. While it provides for variable weights for each element, it automatically generates a normalized sum of the several weights. This is well illustrated by the general form for the weights in the weighted moving average as follows:

$$\text{Total Weight} = \frac{\sum_{i=1}^{\alpha} w_i}{n} \quad (1)$$

where  $w_i$  equals the weight given to the  $i^{\text{th}}$  item and

$$n = \sum_{i=1}^{\alpha} w_i \quad .$$

Therefore, the total weight is unity and the individual weights are mathematically relatable. A very serious problem with this method is the difficulty of assigning weights. A tendency should exist to assign a weight to each attribute that would reflect the relative importance of that attribute with respect to all others. Such a task would be a return to the very complex procedures noted in the literature search. This would seriously violate the need for maximum user simplicity.

### Exponential Weighting

Previous consideration of weighting techniques used in forecasting brings up the method known as the exponentially weighted moving average (also called exponential smoothing). When used with forecasting, exponential weighting assigns weights to historical data in inverse proportion to its age. If exponential weighting is coupled with a simple 1, 2, 3, ...,  $n$ , ranking of the importance of each of a set of attributes, weights can readily be assigned in direct proportion to the relative importance of each of that set of attributes.

The file screening method must recognize and permit the existence of individual user differences during the screening process. Once the user establishes the importance

ranking of the set of attributes, exponential weighting will accomodate the implied order of preference. In addition, this method exhibits the features of ease of use, of mathematical relatability, of being recursive and of allowing uncomplicated (and time consuming) computer operation. Once the user has defined the preferred order of importance by simply assigning the ranks of 1, 2, 3, . . . ,  $n$ , weight generation is essentially automatic.

In describing the method of exponential weighting,  $\alpha$  is used as a sensitivity factor representing the degree of weight given the attribute having the most importance (i.e., a rank of one). In like manner,  $\alpha(1 - \alpha)$  represents the degree of weight given the second most important attribute,  $\alpha(1 - \alpha)^2$  for the third most important, and  $\alpha(1 - \alpha)^{n-1}$  for the  $n^{\text{th}}$  most important attribute. Each attribute weight is separate, distinct and mathematically relatable. In addition, all of the attribute weights sum to unity, thus automatically providing a normalized scheme of weights. This can easily be proved as follows:

$$\begin{aligned} \text{Total Weight} = & \alpha + \alpha(1 - \alpha) + \alpha(1 - \alpha)^2 + . . . + \\ & \alpha(1 - \alpha)^n + . . . \end{aligned} \quad (2)$$

Equation (2) is of the general form:

$$a + ar + ar^2 + . . . + ar^n + . . . \quad (3)$$

which is a convergent infinite series having the sum of  $a/(1 - r)$  when  $r < 1$ . In relating the series of Equation (3) to the series of Equation (2),  $a$  represents  $\alpha$  and  $r$  represents  $1 - \alpha$ . Therefore, Equation (2) is equal to  $\alpha/\alpha$ ,

which is equal to one. In other words, the total weight is unity.

#### Attribute Weight Generation

Figure 1 illustrates the ease of recursive computer generation of the set of weighting factors. The operation is accomplished by initializing the  $i$  index with the value of one. This, and all other indices used in the total procedure, must have only positive, non-zero values. The first element in the WEIGHT vector is given the value of  $\alpha$ , the sensitivity factor. The  $i$  index is then incremented by one. The  $i^{\text{th}}$  element of the WEIGHT vector is given the value of  $1 - \alpha$  raised to the  $i - 1$  power after multiplication by  $\alpha$ . Next, the  $i$  index is checked to see whether the number of evaluated WEIGHT vector elements is equal to the quantity ( $n$ ) of entity attributes. If an insufficient quantity of evaluations has been performed, the index incrementing, evaluating and quantity checking steps are repeated as may be necessary.

#### Attribute Quantification

At this point in the development of the model, a usable, normalized weighting scheme has been acquired. The attribute weights are immediately determinable from the importance order ranking of 1, 2, 3, . . . ,  $n$ , given to the attributes in the file records to be retrieved. Lacking, however, is a numerically valued attribute which can be

0	$i = 1$
1	$\text{WEIGHT}_i = \alpha$
2	$i = i + 1$
3	$\text{WEIGHT}_i = \alpha(1 - \alpha)^{i-1}$
4	$i : n \quad < \rightarrow 2$

Figure 1. Generation of  
Attribute  
Weights

multiplied by the weight factor. A return to the basic method of computer operation offers a possible solution. Computers operate in the binary mode. A switch is either on or off; a particle has a charge or it does not; the value of a memory or register bit is either one or zero.

The concept of a binary mode is useful to the retrieval problem. It can be used with an attribute match valued as a one and a non-match valued as a zero. An alternate method could use the storage of a zero or one (or other number) to indicate the non-existence or existence, respectively, of the attribute. Either method provides a quantitative attribute value during the retrieval process.

The preferable method incorporates the storage of a number rather than an alphanumeric or mnemonic descriptor because the required space to store numerics is much less. In addition, numeric comparisons can be executed much more rapidly than can non-numeric value checks. In general, a binary scheme is very desirable since data coding is readily accomplished. Decision-making is simplified since the attribute either exists or it does not exist for the entity being prepared for entry into the data base.

Where attribute stratification is desirable for certain entities or entity attributes, decimal digits can be used without change in either the storage or retrieval process. Examples of likely need for attribute stratification might be the price of a piece of property in thousands of dollars, the size of a piece of land in tens or hundreds of acres, or

the ability of a worker to stand in the job situation as a zero for not at all, a one for some but not more than one third of the time or a two to represent the ability to stand more than one third of the time.

### Sensitivity Factor Selection

Theoretically, any value within the range of zero to one may be used for the sensitivity factor ( $\alpha$ ). There are, however, practical limits on the value to be used in any given application of nonparametric multivariant attribute retrieval. The first one hundred and fifty elements of Equation (2) were evaluated and summed for several different values of  $\alpha$ . The results have been summarized and presented in Table I. While the computations were carried to a precision of sixteen significant digits, only four significant digits have been present in Table I.

It should be noted that a large sensitivity factor should be used only when there are few attributes being checked for the various entities, or when fairly high sensitivity is desired as concerns the existence of the several most important attributes. When entities having many attributes are being scored for possible retrieval, a small sensitivity factor should be considered.

Table II contains values of  $\alpha$  that might be considered for various ranges of numbers of attributes. The lowest number in each range (of attribute quantities) is the point where the score reaches a value of .9999. The highest

TABLE I

SCORE AFTER SUMMING  $i$  ELEMENTS OF EXPONENTIAL WEIGHTING SERIES FOR SELECTED  $\alpha$  VALUES

$i$	Selected Values of $\alpha$						
	0.01	0.03	0.05	0.07	0.10	0.15	0.20
1	0.0100	0.0300	0.0500	0.0700	0.1000	0.1500	0.2000
5	0.0490	0.1413	0.2262	0.3043	0.4095	0.5563	0.6723
10	0.0956	0.2626	0.4013	0.5160	0.6513	0.8031	0.8926
20	0.1821	0.4562	0.6415	0.7658	0.8784	0.9612	0.9885
40	0.3310	0.7043	0.8715	0.9451	0.9852	0.9985	0.9998
60	0.4528	0.8392	0.9539	0.9871	0.9982	0.9999	*
80	0.5525	0.9126	0.9835	0.9970	0.9998	*	*
100	0.6340	0.9524	0.9941	0.9993	0.9999	*	*
125	0.7153	0.9778	0.9984	0.9998	*	*	*
150	0.7785	0.9896	0.9995	0.9999	*	*	*

\* essentially unity



TABLE II  
SUGGESTED VALUES OF  $\alpha$  FOR ATTRIBUTE  
QUANTITY RANGES

$\alpha$	Number of Attributes
0.01	> 700
0.02	456 - 700
0.03	303 - 456
0.04	226 - 303
0.05	180 - 226
0.06	149 - 180
0.07	128 - 149
0.10	88 - 128
0.15	57 - 88
0.20	42 - 57
0.25	33 - 42
0.30	26 - 33
0.35	22 - 26
0.40	19 - 22
0.45	16 - 19
0.50	14 - 16
0.55	12 - 14
.	.
.	.
.	.
1.00	1

number in each range is the point where the score for the next smallest  $\alpha$  reaches .9999. At any point within each range (of attribute quantities), the score is essentially unity. While larger values for  $\alpha$  (than are shown in Table II) can be used, the value of score becomes essentially unity after only a very few attributes have been checked.

### Retrieval Vector Construction

A simple diagram should illustrate the method of preparing retrieval vectors for the task of screening data base entities for possible selection. Figure 2 has been prepared to provide the needed illustration. The retrieval vectors are constructed from an input vector (ENTRY) which contains a series of the item numbers (of the list of  $n$  attributes) of the sought attributes, the importance number of each attribute (as 1, 2, 3, . . . ,  $n$ ) and the required strata value for the attribute. The input vector is structured to contain three elements for each attribute. This structure is depicted in Figure 3. The first three elements of the input vector contain respectively the importance number of the attribute, the item number of the sought attribute and the required strata or binary value for that attribute. The next three elements of the input vector contain the same items for a second sought attribute, and so forth.

Retrieval vector construction (Figure 2) begins by initializing the  $k$  index with the value of one, the  $l$  index with the value of  $k$  plus one and the  $m$  index with the value

0	$k = 1$
1	$\ell = k + 1$
2	$m = \ell + 1 = k + 2$
3	$i = \text{ENTRY}_k$
4	$j = \text{ENTRY}_\ell$
5	$\text{ORDER}_i = j$
6	$\text{STRATA}_j = \text{ENTRY}_m$
7	$k = k + 3$
8	$k/3 : n < \rightarrow 1$

Figure 2. Construction  
of the  
Retrieval  
Vectors

Position	ENTRY Vector
1	First attribute's importance number
2	First attribute's item number
3	First attribute's strata value
.	. . .
.	. . .
.	. . .
$k$	$n^{\text{th}}$ attribute's importance number
$\ell$	$n^{\text{th}}$ attribute's item number
$m$	$n^{\text{th}}$ attribute's strata value

Figure 3. Structure of ENTRY Vector

of  $k$  plus two (or  $\ell$  plus one). The  $i$  index is given the value of the  $k^{\text{th}}$  element in the input vector (importance number). The  $j$  index is given the value of the  $\ell^{\text{th}}$  element in the input vector (the attribute's item number). The  $i^{\text{th}}$  element of the ORDER vector is set equal to  $j$  (the attribute item number). Figure 4 illustrates the arrangement of the ORDER vector. The  $j^{\text{th}}$  element of the STRATA vector is set equal to the  $m^{\text{th}}$  element in the input vector (the attribute's strata value). Figure 5 illustrates the arrangement of the STRATA vector. The  $k$  index is incremented by three and if all the sought attributes have not been stored in the retrieval vectors, the procedure is repeated beginning with evaluating the  $\ell$  index.

An illustration containing some values might aid in understanding the retrieval vector construction procedure. Suppose an ENTRY vector exists which contains the values: 5, 1, a, 1, 4, b, 3, 2, c, 4, 5, d, 2, 3, and e. Figure 6 shows the contents of the ORDER and STRATA vectors after completion of the retrieval vector construction procedure.

### Retrieval Process

The retrieval process is relatively simple. Figure 7 contains a diagram which illustrates the heart of the retrieval activity. In an operating application, the process is somewhat more complicated because of the need to keep track of which entity is being checked for possible withdrawal. The first step involves clearing the adding machine

Position	ORDER Vector
1	Item number of the most important attribute
2	Item number of the second most important attribute
.	...
.	...
.	...
$i$	Item number of the $i^{\text{th}}$ most important attribute

Figure 4. ORDER Retrieval Vector

Position	STRATA Vector
1	Strata value of attribute number one
2	Strata value of attribute number two
.	. . .
.	. . .
.	. . .
$j$	Strata value of $j^{\text{th}}$ attribute

Figure 5. STRATA Retrieval Vector

Position	ORDER Vector	STRATA Vector
1	4	a
2	3	c
3	2	e
4	5	b
5	1	d

Figure 6. Completed ORDER and STRATA  
Retrieval Vectors



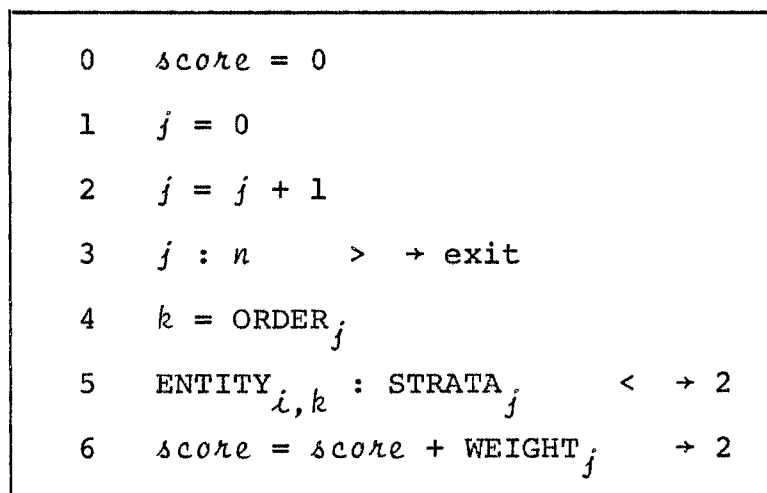


Figure 7. Retrieval Process

(*score*) which is used to accumulate the WEIGHT of the entities' attributes that have been found to be acceptable. Also cleared is the  $j$  index followed by an incrementing by one. The index is then checked to see if all of the attributes of interest have been checked. If all have been checked, control exits to another segment of the overall procedure. If all have not been checked, the  $k$  index is given the  $j^{\text{th}}$  value of the retrieval vector ORDER (the attribute's item number). Next the strata value of the  $k^{\text{th}}$  attribute of the  $i^{\text{th}}$  ENTITY is compared with the required STRATA level of the  $j^{\text{th}}$  most important attribute of the retrieval vector. If the file attribute's strata level is less than required, control returns to increment the  $j$  index and begin a check of the next attribute. If an acceptable strata level is found, the *score* accumulator is incremented by the value of that attribute's WEIGHT and control returns to begin checking the next attribute.

#### Pushdown Storage

Nonparametric multivariant attribute retrieval is intended as a procedure to screen a file of entities and to retrieve the  $m$  (for example, ten) entities having the greatest probability of satisfying the purpose of a specific information retrieval exercise. To accomplish this goal, there is a need to hold information on the  $m$  best entities. This is accomplished by updating a series of  $m$  position, pushdown storages whenever an entity is found for which a

*score* is accumulated that is within the range of the best  $m$  entities found through that point of the entire process. Information items for the new candidate are placed in the pushdown storages on the basis of the accumulated *score* of that entity compared with the *scores* of all other saved entities. That entity having the lowest *score* is dropped from the pushdown units.

Figure 8 contains a diagram which illustrates the operation of the pushdown storages. Entry into this procedure results from exiting the retrieval segment depicted in Figure 7. The process begins by initializing the  $ii$  index with the value one. The range of  $m$  acceptable *scores* are stored in the RESULT vector. The  $ii^{\text{th}}$  element in RESULT is compared with the current entity's *score*. If the  $ii^{\text{th}}$  stored value is greater than *score*, the  $ii$  index is incremented by one, compared with  $m$  and if not greater, control returns to make a comparison with the next element in RESULT. The procedure exit leads to the start of retrieval scoring on a new entity. If the value of *score* is found to be greater than the value of the element in RESULT, the pushdown operation is started. The  $jj$  pointer is set equal to the algebraic sum of the  $ii$  index plus  $m$  less one. This pointer is used to permit the contents of the  $m-1^{\text{th}}$  position of a pushdown storage to be moved to the  $m^{\text{th}}$  position, the contents of the  $m-2^{\text{th}}$  position to be moved to the  $m-1^{\text{th}}$  position, etc. Figure 9 contains a use of the RESULT vector to graphically depict this pushdown movement. Next, the  $jj$  index is

```

0     $ii = 1$ 
1     $\text{RESULT}_{ii} : \text{score} \leq \rightarrow 4$ 
2     $ii = ii + 1$ 
3     $ii : m \leq \rightarrow 1$ 
4     $jk = m - 1 + ii$ 
5     $jj = ii$ 
6     $mn = jk - jj$ 
7     $mn : ii < \rightarrow 16$ 
8     $ln = mn + 1$ 
9     $ln : m > \rightarrow 16$ 
10    $\text{RESULT}_{ln} = \text{RESULT}_{mn}$ 
11    $l = 0$ 
12    $l = l + 1$ 
13    $l : mm > \rightarrow 15$ 
14    $\text{TBL}_{l,ln} = \text{TBL}_{l,mn} \rightarrow 12$ 
15    $jj = jj + 1 \rightarrow 6$ 
16    $\text{RESULT}_{ii} = \text{score}$ 
17    $l = 0$ 
18    $l = l + 1$ 
19    $l : mm > \rightarrow \text{exit}$ 
20    $\text{TBL}_{l,ii} = \text{ATTR}_{i,l} \rightarrow 18$ 

```

Figure 8. Pushdown Storage

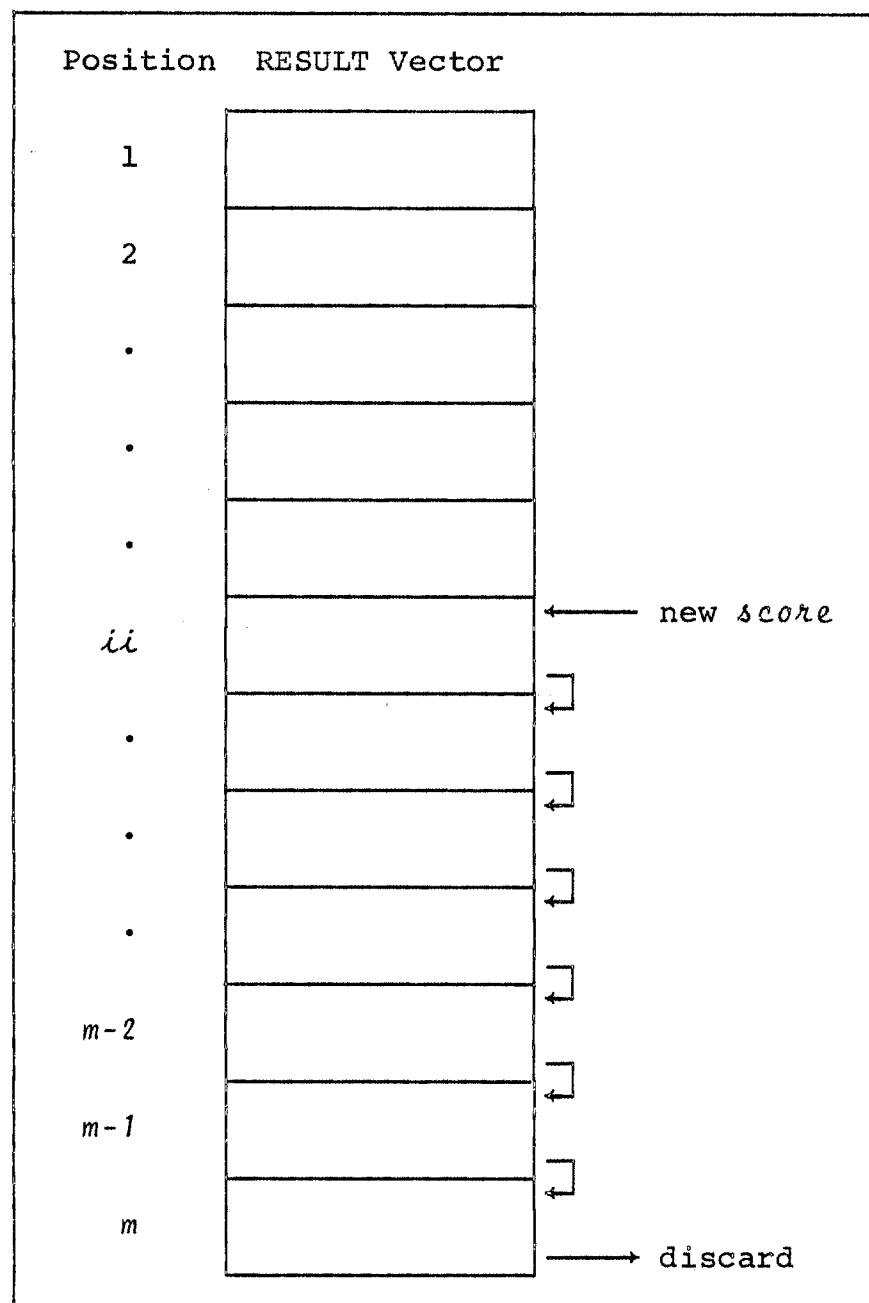


Figure 9. Pushdown Storage Operation Using  
RESULT Vector as an Example  
(activity progresses from  
*m*th element to the *i*th  
element)

set equal to  $ii$ . The  $mn$  index is given the value of the  $jk$  pointer less the value of the  $jj$  index (this value should initially be the same as  $m-1$ ). The value of the  $mn$  index is compared with  $ii$ . If  $mn$  is less (which indicates that the new savable *score* is to replace the one in the  $ii^{\text{th}}$  storage position), control transfers to the group of statements which store values for the current entity. The  $ln$  index is given the value of  $mn$  plus one, which should initially be the same as the value of  $m$ . The value of the  $ln$  index is compared with  $m$ . If  $ln$  is greater (which indicates that the new savable *score* is to replace the one in the  $m^{\text{th}}$  storage position), control transfers to the group of statements which store values for the current entity. If  $ln$  is not greater, the actual task of pushing down file entries is started. First, one entry in the RESULT vector is moved. The  $l$  index is cleared and then incremented by one. The value of  $l$  is compared with  $mm$  (the quantity of attributes being held for any one entity). If  $l$  is greater, the  $jj$  index is incremented and control returns to prepare for the pushdown movement of the next smallest scored entity being kept in the storage. If  $l$  is not greater than  $mm$ , the  $l^{\text{th}}$  attribute in the TBL storage matrix is moved. The  $l$  index is incremented and that portion of the procedure is resumed. After the attributes for the lowest scored  $m-ii$  entities (of the stored entities) have been pushed down one position, a series of storage positions have been opened to save the several attributes of the new entity. The remaining several

steps perform that task. The *score* of the current entity is placed in the  $i^{th}$  position of the RESULT vector. The remaining steps perform the task of saving the several attributes of the new entity.

An illustration showing the result of a pushdown storage operation might be helpful. Figure 10 depicts the arrangement of the contents of the RESULT vector before and after insertion of a newly found *score* which is large enough to require retention. Suppose the value of the newly found *score* is 85.67. As illustrated, the new *score* fits between 85.64 and 87.16. Insertion of the new *score* causes the value 85.64 to drop one position and the value 83.92 to be discarded from the storage unit.

### Output

Output from the retrieval procedure would be dependent upon the specific application. Generally, the displayed information would consist of the contents of the RESULT vector and the pushdown matrix which has been called TBL. In some applications, it might be desirable to store and display non-numeric information. This might require the use of an additional pushdown matrix that was structured to be able to handle quantities of non-numeric information.

Position	RESULT Vector (before)	RESULT Vector (after)
1	92.75	92.75
2	91.68	91.68
3	89.85	89.85
4	87.16	87.16
5	85.64	85.67
6	83.92	85.64

Figure 10. Illustration of Pushdown  
Storage Operation



## CHAPTER III

### SPECIFIC APPLICATION OF MODEL

One potentially useful application of nonparametric multivariant attribute retrieval lies in the area of matching the abilities of people with the capabilities required for successful performance of a given job. This application should be especially useful when attempting to acquire jobs for persons having physical and/or mental handicaps.

In 1969, Dalal (8) proposed a list of worker characteristics, physical activities, and working conditions that should be considered when preparing to hire an individual for a job. Appendix A contains a listing of his suggestions (structured as a form) as concerns the requirements of a specific job. The intent was to record the results of a careful job audit on the several pages of the form. Worker selection would be made by comparing the recorded job characteristics with numerous somewhat similar forms (see Appendix B) on which the abilities of persons had been recorded. Dalal also wrote a computer program which checked for an absolute match between the applicants' abilities and the requirements of the job. Definitions of the terms used on both of the forms are included as Appendix C.

### Trial Sample

Dalal's forms have been modified somewhat for use with nonparametric multivariant attribute retrieval. The modified job requirements form appears in Appendix D and the modified worker characteristics form appears in Appendix E. The definitions of terms presented in Appendix C are applicable to both of the modified forms. The major modification comprises the need for an importance ranking of the job characteristics. The task of ranking the importance of the necessary job characteristics would be accomplished during the audit of the job position. While the formality of careful evaluation and recording of the characteristics of a job may be somewhat different from much of actual practice, such a record provides an excellent means of communicating the abilities needed in a potential employee. In a similar fashion, the recording of worker abilities goes only a little further than does much of the actual practice in evaluating the potential of an individual to handle a particular job. The primary difference pertains to evaluating the individual from a general standpoint, rather than with respect to a particular job opening. Probably the best place for such an evaluation to be accomplished is a major employment agency, such as one operated by a state or by an agency devoted to locating gainful employment for the handicapped.

## Description of Procedure

The purpose of this chapter is not to provide a defense for a particular group of job characteristics and worker abilities but rather to illustrate the details of the data screening and information retrieval procedure. The computer program utilized for the screening process is included as Appendix F. Appendix G contains an APL (A Programming Language) description of the procedure as applied to the task of obtaining a list of candidates having a higher probability of fitting the needs of a particular job than do other persons not selected by the screening process. Much of the remainder of this chapter is devoted to a segment by segment explanation of the screening process as illustrated by Appendix G.

APL was selected to serve as the vehicle for presenting the documentation of an application of nonparametric multivariant attribute retrieval because of the conciseness and potential clarity of APL as compared with such vehicles as flow charting. Iverson (9) made the following remarks when introducing his "A Programming Language":

The systematic treatment of complex algorithms requires a suitable programming language for their description, and such a programming language should be concise, precise, consistent over a wide area of application, mnemonic, and economical of symbols; it should exhibit clearly the constraints on the sequence in which operations are performed; and it should permit the description of a process to be independent of the particular representation chosen for the data.

Existing languages prove unsuitable for a variety of reasons. Computer coding specifies

sequence constraints adequately and is also comprehensive, since the logical functions provided by the branch instructions can, in principle, be employed to synthesize any finite algorithm. However, the set of basic operations provided is not, in general, directly suited to the execution of commonly needed processes, and the numeric symbols used for variables have little mnemonic value. Moreover, the description provided by computer coding depends directly on the particular representation chosen for the data, and it therefore cannot serve as a description of the algorithm per se.

Ordinary English lacks both precision and conciseness. The widely used Goldstine-von neumann flowcharting provides the conciseness necessary to an over-all view of the process, only at the cost of suppressing essential detail. The so-called pseudo-English used as a basis for certain automatic programming systems suffers from the same defect. Moreover, the potential mnemonic advantage in substituting familiar English words and phrases for less familiar but more compact mathematical symbols fails to materialize because of the obvious but unwonted precision required in their use.

The APL description begins with steps AR0 through AR4. These steps are concerned with the task of entering the records of each possible applicant. These records include, in addition to such items of identification as name, social security number and sex, a vector which contains a strata value for each attribute recorded for the applicant. The sequence begins with clearing the *na* index (number of applicants) and then incrementing it by one. The first card of a two card applicant record is read and stored. The contents of the social security field (SOCS) is compared with the end-of-file signal to see if all applicant records have been entered. If the end-of-file signal is detected, control is transferred to the next segment of the procedure. If the

signal is not detected, the remainder of that applicant's record is entered, the *na* index is incremented and the steps are repeated.

Steps AR5 through AR15 are utilized to clear all of the vectors and pushdown storages which are involved with the tasks of data screening and attribute retrieval for a particular job opening. The entire procedure, beginning with step AR5 and continuing through step AR123, is repeated if more than one job opening is being considered. Step AR5 decrements the *na* index to remove the end-of-file signal which would be included in the count by step AR1. The elements of the JOB (will later contain the required attribute stratas) and the ORDER (will later contain the attribute item numbers in their sequence of importance) vectors are set to zero. All positions of the RESULT pushdown vector (used to store the scores of the best ten applicants) are cleared. The TBL pushdown matrix (used to store five items of information concerning the ten best applicants) is cleared. All elements in the SAVSEX pushdown vector (used to store the sex of the ten best applicants) are cleared with a blank character. The elements of the BSTPOR pushdown matrix (used to record the instances of better and poorer attribute strata values of the ten best applicants) are cleared. All elements of the WHO pushdown matrix (used to store the names of the ten best applicants) are cleared with a blank character.

Steps AR16 through AR37 are concerned with the input and placing of the identification and job requirement vectors and is very similar to the illustrations contained in Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6. The sequence begins with the reading of a card containing job identification entries. The existence of an end-of-file signal is checked. If the end-of-file signal has been read, the entire retrieval procedure is terminated. Otherwise, *rank* (a pointer used to record the number of job attributes) is cleared. A card containing *jobcd* (an element used to keep together all input cards which describe a single job opening), *alpha* (the weight sensitivity factor) and the ENTRY input vector (described in the section on Retrieval Vector Construction in Chapter II) is read. The remaining steps in this segment are used to store the elements contained in the ENTRY vector. The procedure continues by setting the  $k$  index to one, the  $\ell$  index to  $k$  plus one, and the  $m$  index to  $k$  plus two (or  $\ell$  plus one). The  $n$  index is set equal to the  $k$  index. Steps AR24 through AR26 are used to be certain that only non-zero entries are received into the retrieval vectors. If any element within a group is found to be zero, the group is discarded by a control transfer to the end of the processing loop. This is done to save processor time during later portions of the retrieval process. The  $i$  index is given the value of the  $k^{\text{th}}$  element in the ENTRY vector. The  $j$  index is given the value of the  $\ell^{\text{th}}$  element in the ENTRY vector. The  $i^{\text{th}}$  element in the ORDER

vector is checked for a value of zero. If this value is not zero, it indicates an attempt to store two or more elements in one place. This is not feasible, therefore the second (or later) set is discarded by a control transfer to the end of the processing loop. The  $i^{\text{th}}$  element in the ORDER vector is given the value of  $j$ . This stores the item number of the job attribute into its importance position in the ORDER vector. Step AR31 causes the required strata value to be placed into a position within the JOB attribute vector that corresponds with that attribute's item number. Step AR32 is used to determine whether the current attribute's importance number is the largest yet processed. If it is, that number is stored in the *rank* index. The *rank* index is used as the cycle maximum for a looping segment later in the procedure. The *k* index is incremented by three in preparation for processing the next three elements in the ENTRY vector. Step AR35 is used to determine whether all elements in the ENTRY vector have been processed. If not, control returns to continue that processing, otherwise another record is read. If the job opening code in the new record matches the code in the previous record, control returns to process and store the contents of the new record. If the codes are different, the retrieval processing can begin after the vector containing the attribute weights has been generated. The steps involved in this task are similar to those described in the section on Attribute Weight Generation in Chapter II.

The remaining steps in the procedure are very similar to the theoretical activities described in the sections entitled Retrieval Process and Pushdown Storage presented in Chapter II. Primary differences between the theory and the actual practice involve the quantity of items held in the pushdown storage facilities and the peculiarities needed to handle non-numeric versus numeric information.

#### Example Output

An illustration of the actual output from the procedure is contained in Table III. In addition to the usual identification items such as the name, social security number, and the sex of the applicant, several other useful items of information have been developed and displayed. The applicant's match value is shown. This is the weighted *score* which has been multiplied by one hundred to place it in the usual scale range of one through one hundred. During the screening and retrieval process, a notation has been made of the number of instances wherein the applicant's attribute strata value has exceeded the requirements of the job opening. In addition, the item number of up to the ten most important of these attributes has been displayed. A similar notation and display has been provided for the situations wherein the applicant failed to meet the requirements of the job opening.

The better and poorer information is included as an aid to the decision-making process. While a programmed decision



TABLE III  
ILLUSTRATION OF PROCEDURE OUTPUT

RESULTS OF SEARCH ON JOB OF POCKET SEWER & COLLAR SETUP																
RANK	MATCH VALUE	NAME	SOCIAL SECURITY NUMBER	SEX	QUALIFICATIONS VS SPECIFICATIONS. NUMBER OF INSTANCES WHERE		UP TO TEN SPECIFIC FACTORS WHEREIN INDIVIDUALS QUALIFICATIONS									
					BETTER	POORER	ARE BETTER					ARE POORER				
1	87.69014	TESTING, IMA	987-65-4321	M	21	0	23	31	36	1	11					
							9	8	10	14	19					
2	84.10994	GODLEY, MARGARET	243-52-3695	F	8	5	36	1	11	9	8	38	21	35	67	63
							10	51	68							
3	70.25542	BERNDSEN, PAULA	465-68-9650	F	7	13	23	31	36	9	51	18	16	7	20	35
							68	64				71	56	98	10	54
4	61.92137	HATTER, RICK	322-30-6303	M	3	24	31	36	68			6	7	37	38	71
												45	67	66	63	11
5	57.92906	POLAKOFF, I. I.	305-44-1737	M	2	26	31	36				40	6	7	84	85
												72	71	56	45	63
6	54.07971	GRABBOY, JAN	416-64-1508	F	7	15	31	11	9	8	10	28	18	16	29	40
							51	68				20	30	38	39	35
7	52.87445	HORSCHLER, NELDA	147-33-2359	F	2	28	31	36				16	96	44	6	7
												35	84	85	72	71
8	52.00304	ELLIOT, C. M. D.	423-58-4873	M	2	29	31	36				16	6	7	37	21
												84	85	71	56	45
9	32.84001	HUPMAN, GEORGE	445-44-9752	M	1	33	68					28	29	40	96	97
												44	6	7	22	37

process could be used whereby a job offer could be made to the best applicant, such is not a good policy. Every situation contains qualitative factors. Even when it is possible to attach numerical values to each of many factors, certain interrelations between the several attributes are not likely to be well depicted. The human mind is still better equipped to make the final determination. The procedure contained in nonparametric multivariant attribute retrieval merely narrows the myriad of possible choices to a few manageable decisions.

## CHAPTER IV

### OTHER APPLICATIONS

Chapter II contained a presentation of the theory and the general method of file screening and information retrieval as proposed in nonparametric multivariant attribute retrieval. The details for a specific application, matching the abilities of people with the capabilities required for successful performance of a given job, were presented in Chapter III. The remainder of this chapter is directed toward the introduction of several other possible applications of the method.

#### Industrial Site Selection

The selling of the features of a state to an expanding or move-minded firm is a rather involved process. It is initiated by a letter from the firm requesting some information about the state, a phone call from some firm or an industrial response to a selective mailing made by a state's industrial board or commission. Early correspondence between a state and the firm is usually limited to each learning about the other.

Industrial relocation usually occurs for the purpose of economic advantage such as closer proximity to markets

and/or raw materials or suppliers, or lower costs for the various factors of production. Much economic benefit accrues to the state receiving the relocated facility. These benefits are in the form of an increased tax base, employee salaries, increased shipping, and a multitude of secondary monetary exchanges.

Much competition exists between the various states for the favors of expanding and relocating businesses. Informative brochures are prepared and distributed which present the industrial merits of most communities, transportation facilities, tax structures, labor costs, and resource survey findings. Unfortunately, published information, while well presented, is outdated and only current information is readily useful for properly presenting the economic merits of a particular locality or state.

The usefulness of published information is further reduced by the varying information needs and the relative importance of each specific element as viewed by different business firms. For example, because of the need to ship or receive vast quantities of bulk material, some firms must be located adjacent to waterway facilities. In a like manner, other firms have varying paramount requirements.

Appendix H contains a form having a partial listing of the elements considered when a firm attempts to select a specific piece of land for a new facility. While many more factors would be considered, the listed items give an idea as to the workings of nonparametric multivariant attribute

retrieval for this particular situation. Significant differences between this application and the task of matching jobs and applicants exists in the type of data stratification to be handled. In the case of jobs versus applicants, data was stratified as a zero, a one, or a two where these respectively related to no need or no ability, minor need or minor ability, and major need or major ability. In the case of site selection, the data contains a large quantity of binary yes/no answers along with several maximum and minimum numeric designators. The program used earlier would need to be slightly modified to handle the binary items for some elements as well as the greater than or equal to (minimum) and less than or equal to (maximum) requirements. Outside of the questions concerning applicant sex, all of the items in the jobs versus applicants situation were of a greater than or equal to nature. Appendix I contains a listing of the program, which has been modified to accept equal to, less than or equal to, and greater than or equal to constraints. An illustration of the actual output from the modified program applied to a site selection situation is contained in Table IV.

Industrial site selection provides an interesting application for the proposed file screening procedure. Conway Research, Incorporated (10) periodically publishes a "Site Selection Checklist". This checklist includes twenty-three major interest concerns. These major interest areas contain a set of attributes which may total a thousand or

TABLE IV

## ILLUSTRATION OF OUTPUT FROM MODIFIED PROCEDURE

## RESULTS OF SEARCH FOR LOCATION FOR ACME MANUFACTURING FILE 10.1-72A

RANK	MATCH VALUE	LOCATION	FILE NUMBER	CHARACTERISTICS VS SPECIFICATIONS. NUMBER OF INSTANCES WHERE		UP TO TEN SPECIFIC FACTORS WHEREIN ENTITY QUALIFICATIONS	
				BETTER	POORER	ARE BETTER	ARE POORER
1	94.66310	MOBILE	305-441-737	4	2	1 19 18 16	17 20
2	94.32567	TULSA	650- 42-103	4	2	1 19 18 17	16 20
3	92.94521	CINCINNATI	243-523-695	3	3	1 19 18	16 17 20
4	82.97055	BUFFALO	416-641-508	4	2	1 18 16 17	19 20
5	79.61638	SALISAW	322-306-303	4	2	1 18 17 20	19 16
6	78.82079	ATLANTA	147-332-359	3	3	1 18 17	19 16 20
7	67.29079	BIRMINGHAM	557-387- 19	3	2	1 19 16	18 20
8	61.60986	LOCKPORT	423-584-873	3	2	1 19 17	18 20
9	59.65521	COLUMBUS	411-411- 41	3	3	19 18 16	1 17 20
10	57.23860	STILWELL	210- 31-100	2	4	19 18	1 16 17 20

more elements when fully evaluated and, if all are included, will require a large amount of effort during the assembly of the data file.

### Dwelling Selection

The increasing mobility of large segments of the American public generates major housing problems. The typical quantity of time and effort required to find suitable housing in the new community generally occurs during the period when necessary time is not available and the involved persons are physically and emotionally tired from the task of pulling up roots, deciding on possessions to discard, saying farewell to friends, packing, and traveling.

Dwelling selection frequently involves want ad perusal, extensive use of a telephone, visits to real estate agents, and much driving from unit to unit to personally view and evaluate the suitability potential of a myriad of dwellings. Endless discussions are also required to finally narrow the possibilities to one or a few units. During this period, the individual or family may be living in expensive, temporary quarters such as a hotel or motel. The impending arrival of household goods lends urgency and frustration to the situation.

Some attempts have been made to involve the computer in the process of reducing the number of possible alternatives among which a client may make a decision. Appendix J contains a form having a partial listing of the elements to be

considered when attempting to select a dwelling. While many more factors would be considered, the listed items give an idea as to the workings of nonparametric multivariant attribute retrieval for this particular situation. It should be noted that this application is identical to that of industrial site selection presented in the previous section. All attributes are either of the binary yes/no type or of the maximal/minimal value type. The version of the program listed in Appendix I will fit the situation of dwelling selection without any modification.

#### Miscellaneous Selection Situations

Numerous other situations should be capable of being handled by nonparametric multivariant attribute retrieval. In general, these situations do not appear to differ significantly from those already outlined. Other applications may include matching prospective foster or adoptive parents and orphans, students and colleges, assign compatible roommates to dormitory rooms, and aid in disease diagnosis by symptom matching.



## CHAPTER V

### SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

#### Summary

Nonparametric multivariant attribute retrieval is a file screening method which recognizes and permits the existence of individual user differences during the screening process. This characteristic is considered to be of paramount concern because individual differences or preferences can make a significant impact on the level of user satisfaction with the results from the retrieval activity. Information retrieval systems tend to require fairly rigorous coding and/or key word structures. Rigorous structures presuppose standard preferences and values which do not exist within a set of possible users or even uses of a retrieval system.

The proposed procedure utilizes the decision-maker's order of attribute importance within the various file entities by the use of a scheme of connecting mathematically relatable weights to each attribute of the set of file entities during the retrieval activity. Exponential weighting

was found to provide the needed mathematically relatable weights.

### Conclusions

Nonparametric multivariant attribute retrieval consists of a group of methods which function in a complementary fashion to quantify, order, weight, and calculate the attribute match score for each of a set of entities. Human decision-making procedures are utilized to make the final determination from the set of alternatives having the best match score.

Manual weighting schemes, such as the standard gamble method, while producing mathematically relatable factor weights, suffer from the twin faults of not being readily applicable in a computer and requiring an extraordinary amount of effort - especially when a large number of attributes are being considered.

Exponential weighting, coupled with the position numbers of the decision-maker's order of attribute importance, provides an essentially automatic procedure of weight generation which functions to recognize individual user differences during the file screening process.

Nonparametric multivariant attribute retrieval has wide applicability. Its use includes but is not limited to aiding in matching persons and jobs, industrial firms and plant sites, persons and dwellings, prospective parents and

orphans, students and colleges, roommates for assignment to dormitory rooms, and symptoms in disease diagnosis.

### Recommendations

Several related areas exist in which further study may prove beneficial. These are discussed in subsequent paragraphs.

Since a significant portion of the operating cost of a file screening method is caused by central processor time consumption, retrieval processing speed should be compared between the several major problem oriented computer languages (FORTRAN, COBOL, PL/1) and machine language. Such a study will provide the most economical method of operation.

Certain of the possible areas of application for the proposed file screening method contain a vast number of attributes. One such application is that of industrial site selection. The various attributes can be combined into several subgroupings such as markets, labor, transportation, power and fuel, etc. Rather than performing an importance ranking across all attributes, it may be better to perform the importance ranking independently within each of the several subgroupings. Such an approach may grant better consideration for the important attributes in each of the several subgroups.

#### SELECTED BIBLIOGRAPHY

- (1) "The Recession Forces a Reappraisal." Business Week (June 5, 1971).
- (2) Hershman, Arlene "A Mess in MIS?" Dun's Review (January, 1968).
- (3) Churchman, C. West, Russell Ackoff and Leonard Arnoff Introduction to Operations Research. New York: John Wiley and Sons, Incorporated, 1957, p. 136.
- (4) Churchman, C. West, Russell Ackoff and Leonard Arnoff Introduction to Operations Research. New York: John Wiley and Sons, Incorporated, 1957, 139-140.
- (5) von Neumann, John and Oskar Morgenstern Theory of Games and Economic Behavior. Princeton: Princeton University Press, 1947.
- (6) Reed, Ruddell, Jr. Plant Layout. Homewood, Illinois: Richard D. Irwin, Incorporated, 1961.
- (7) Hicks, Philip E. and Arun M. Kumtha "One Way to Tighten Up Plant Location Decisions." Industrial Engineering (April, 1971).
- (8) Dalal, Anilkant T. "Computer Matching of Worker's Qualifications to Job Requirements." (Unpub. M. S. thesis, Mississippi State University, 1969).
- (9) Iverson, Kenneth E. A Programming Language. New York: John Wiley and Sons, Incorporated, 1962.
- (10) "Site Selection Checklist." Industrial Development (October, 1966).

APPENDIX A

SOURCE JOB REQUIREMENTS FORM

Job Requirements Form<sup>1</sup>

PLANT \_\_\_\_\_ JOB \_\_\_\_\_ NORMAL TRAINING PERIOD \_\_\_\_\_

1. Can work be done by both sexes? Y N
2. If "No" in (1) above, which sex is required? M F
3. If "Yes" in (1) above, which sex is preferred? M F
4. Must worker stand? Y N
5. If "Yes" in (4) above, what percent of time will be spent standing? A=(1-10), B=(11-35), C=(36-100) A B C
6. Is walking necessary? Y N
7. If "Yes" in (6) above, what percent of time must individual spend walking? A=(1-10), B=(11-35), C=(36-100) A B C
8. Could worker be blind? Y N
9. Could worker be color blind? Y N
10. Is poor sight permissible? Y N
11. Are both arms necessary to perform the work? Y N
12. The use of arms in lifting is:
  - (A) Light (0-15 lbs., little physical demand, no sustained exertion)
  - (B) Constant Light (0-15 lbs., occasional 15-40 lb. demand)
  - (C) Constant Medium (15-40 lb. demand occasional heavy 40 lbs. and up)
  - (D) Constant Heavy (40 lbs. and up) A B C D
- 13-14. What fingers are required for performing the job?
 

A=(R) All	B=(R) T10	C=(R) Other		A B C
A=(L) All	B=(L) T10	C=(L) Other		A B C

 If "Other", explain: \_\_\_\_\_  
 \_\_\_\_\_

<sup>1</sup>Anilkant T. Dalal, "Computer Matching of Worker's Qualifications to Job Requirements" (unpub. Master's Thesis, Mississippi State University, 1969).

- |  |     |
|--|-----|
| 15. Must the worker be able to hear?                               | Y N |
| 16. Are skin irritants used?                                       | Y N |
| 17. Is the ability to read necessary?                              | Y N |
| 18. Are decisions involving judgment encountered on the job?       | Y N |
| 19. Is job of a nature that a delicate sense of touch is required? | Y N |

WORKER CHARACTERISTICS, PHYSICAL ACTIVITIES  
AND WORKING CONDITIONS

Characteristics Required\*

_____ Work rapidly for long periods	_____ Touch discrimination
_____ Strength of hands	_____ Intelligence
_____ Strength of arms	_____ Adaptability
_____ Strength of legs	_____ Ability to plan
_____ Strength of back	_____ Initiative
_____ Dexterity of fingers	_____ Oral expression
_____ Dexterity of hands and arms	_____ Height
_____ Dexterity of foot and leg	_____ Weight
_____ Eye-hand coordination	_____ Muscular discrimination
_____ Foot-eye-hand coordination	_____ Arithmetic computation
_____ Coordination, both hands	_____ Ability to make decisions
_____ Estimate size of objects	_____ Memory for names and persons
_____ Estimate quantity of objects	_____ Personal appearance
_____ Perceive form of objects	_____ Concentration amidst distractions
_____ Estimate speed of moving objects	_____ Emotional stability
_____ Memory for details (things)	_____ Work under hazardous conditions
_____ Memory for ideas (abstract)	_____ Estimate quality of objects
_____ Memory for oral directions	_____ Unpleasant physical conditions
_____ Understanding mechanical devices	_____ Ability to meet and deal with the public
_____ Attention to many items	
_____ Skill in written experience	
_____ Tact in dealing with people	
_____ Keeness of vision	
_____ Sense of smell	
_____ Sense of taste	

\*Blank indicates not present, not required, not a factor, etc.

"1" indicates presence in job, 0-35% of time, some requirement, fairly important, etc.

"2" indicates important factor in job, 36-100% of time, major requirement, very important, etc.



## Physical Activities\*

<input type="checkbox"/> Walking	<input type="checkbox"/> Carrying
<input type="checkbox"/> Jumping	<input type="checkbox"/> Throwing
<input type="checkbox"/> Running	<input type="checkbox"/> Pushing
<input type="checkbox"/> Balancing	<input type="checkbox"/> Pulling
<input type="checkbox"/> Climbing	<input type="checkbox"/> Handling
<input type="checkbox"/> Crawling	<input type="checkbox"/> Fingering
<input type="checkbox"/> Standing	<input type="checkbox"/> Feeling
<input type="checkbox"/> Turning	<input type="checkbox"/> Talking
<input type="checkbox"/> Stooping	<input type="checkbox"/> Hearing
<input type="checkbox"/> Crouching	<input type="checkbox"/> Seeing
<input type="checkbox"/> Kneeling	<input type="checkbox"/> Color Vision
<input type="checkbox"/> Sitting	<input type="checkbox"/> Depth Perception
<input type="checkbox"/> Reaching	<input type="checkbox"/> Working Speed
<input type="checkbox"/> Lifting	

Working Conditions and  
Hazards\*

<input type="checkbox"/> Inside	<input type="checkbox"/> Adequate Ventilation
<input type="checkbox"/> Outside	<input type="checkbox"/> Vibration
<input type="checkbox"/> Hot	<input type="checkbox"/> Mechanical
<input type="checkbox"/> Cold	<input type="checkbox"/> Hazards
<input type="checkbox"/> Sudden Temperature Change	<input type="checkbox"/> Moving Objects
<input type="checkbox"/> Humid	<input type="checkbox"/> Cramped Quarters
<input type="checkbox"/> Dry	<input type="checkbox"/> High Places
<input type="checkbox"/> Wet	<input type="checkbox"/> Exposure to Burns
<input type="checkbox"/> Dusty	<input type="checkbox"/> Electric Hazards
<input type="checkbox"/> Dirty	<input type="checkbox"/> Explosives
<input type="checkbox"/> Odors	<input type="checkbox"/> Radiant Energy
<input type="checkbox"/> Noisy	<input type="checkbox"/> Toxic Conditions
<input type="checkbox"/> Adequate Lighting	<input type="checkbox"/> Working with Others
	<input type="checkbox"/> Working Around Others
	<input type="checkbox"/> Working Alone

\*Blank indicates not present, not required, not a factor, ect.

"1" indicates presence in job, 0-35% of time, some requirement, fairly important, etc.

"2" indicates important factor in job, 36-100% of time, major requirement, very important, etc.

APPENDIX B

SOURCE PHYSICAL QUALIFICATIONS FORM

PHYSICAL QUALIFICATIONS FORM<sup>1</sup>

ID No. _____	Experience _____
Name _____	Height _____
Sex _____	Weight _____
Age _____	

1. Individual's sex M F
2. Is individual capable of standing? Y N
3. If "Yes in (2) above, indicate percent of time. A=(1-10), B=(11-35), C=(36-100) A B C
4. Is subject capable of walking? Y N
5. If "Yes" in (4) above, indicate percent of time. A=(1-10), B=(11-35), C=(36-100) A B C
6. Is individual totally blind? Y N
7. If "No" in (6) above, is he/she color blind? Y N
8. If "No" in (6) above, does he/she have poor vision? Y N
9. Are both of individual's arms functional? Y N
10. Limitation on arms is as follows:
  - (A) Light (0-15 lbs., little physical demand, no sustained exertion)
  - (B) Constant light (0-15 lbs., occasional 15-40 lb. demand)
  - (C) Constant medium (15-40 lb. demand, occasional 40 lb. and up)
  - (D) Constant heavy (constant 40 lbs. and up)A B C D
- 11-12. Fingers intact for performance of work.
  - A=(R) All B=(R) T10 C=(R) Other A B C
  - A=(L) All B=(L) T10 C=(L) Other A B C
  - If "Other" explain \_\_\_\_\_
13. Is individual deaf? Y N
14. Is individual allergic to any known substances? Y N

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<sup>1</sup>Anilkant T. Dalal, "Computer Matching of Worker's Qualifications to Job Requirements" (unpub. Master's Thesis, Mississippi State University, 1969).

15. Is subject literate? Y N
16. May individual work with complex equipment? Y N
17. Is there an impairment to this individual's sense of touch? Y N
18. Can individual exert large effort for long periods?  
 (A) 75-100% of time.  
 (B) 35-74% of time.  
 (C) 0-34% of time. A B C
19. Does individual's back permit him/her to lift heavy loads?  
 (A) 0-15 lbs., relatively sustained.  
 (B) 15-40 lbs., constant.  
 (C) over 40 lbs., constant. A B C
20. Does individual have any of the following arthritic conditions?  
 (A) Right fingers (H) Left fingers  
 (B) Right wrist (J) Left wrist  
 (C) Right elbow (K) Left elbow  
 (D) Right shoulder (L) Left shoulder  
 (E) Right ankle (M) Left ankle  
 (F) Right knee (N) Left knee  
 (G) Right hip (P) Left hip
21. Does applicant have history of nervous disorder?  
 (A) None (C) Hospitalized  
 (B) Hospitalized 10 yrs. 2 yrs. ago.  
 ago. No recurrence. No recurrence.  
 (D) Problem is prevalent. A B C D
22. Does individual have respiratory problems? Y N

## CHARACTERISTICS OF THE WORKER\*

_____ Work rapidly for long periods	_____ Touch discrimination
_____ Strength of hands	_____ Intelligence
_____ Strength of arms	_____ Adaptability
_____ Strength of legs	_____ Ability to plan
_____ Strength of back	_____ Initiative
_____ Dexterity of fingers	_____ Oral expression
_____ Dexterity of hands and arms	_____ Height
_____ Dexterity of foot and leg	_____ Weight
_____ Eye-hand coordination	_____ Muscular discrimination
_____ Foot-eye-hand coordination	_____ Arithmetic computation
_____ Coordination, both hands	_____ Ability to make decisions
_____ Estimate size of objects	_____ Memory for names and persons
_____ Estimate quantity of objects	_____ Personal appearance
_____ Perceive form of objects	_____ Concentration amidst distractions
_____ Estimate speed of moving objects	_____ Emotional stability
_____ Memory for details (things)	_____ Work under hazardous conditions
_____ Memory for ideas (abstract)	_____ Estimate quality of objects
_____ Memory for oral directions	_____ Unpleasant physical conditions
_____ Understanding mechanical devices	_____ Ability to meet and deal with the public
_____ Attention to many items	
_____ Skill in written experience	
_____ Tact in dealing with people	
_____ Keeness of vision	
_____ Sense of smell	
_____ Sense of taste	

\*Blank indicates not present, disability.

"1" indicates the person can perform the characteristic for 0-35% of time or fair ability.

"2" indicates the person can perform the characteristic for 36-100% of time or sound ability.

Physical Activities the Person  
Can Perform\*

<input type="checkbox"/> Walking	<input type="checkbox"/> Carrying
<input type="checkbox"/> Jumping	<input type="checkbox"/> Throwing
<input type="checkbox"/> Running	<input type="checkbox"/> Pushing
<input type="checkbox"/> Balancing	<input type="checkbox"/> Pulling
<input type="checkbox"/> Climbing	<input type="checkbox"/> Handling
<input type="checkbox"/> Crawling	<input type="checkbox"/> Fingering
<input type="checkbox"/> Standing	<input type="checkbox"/> Feeling
<input type="checkbox"/> Turning	<input type="checkbox"/> Talking
<input type="checkbox"/> Stooping	<input type="checkbox"/> Hearing
<input type="checkbox"/> Crouching	<input type="checkbox"/> Seeing
<input type="checkbox"/> Kneeling	<input type="checkbox"/> Color Vision
<input type="checkbox"/> Sitting	<input type="checkbox"/> Depth Perception
<input type="checkbox"/> Reaching	<input type="checkbox"/> Working Speed
<input type="checkbox"/> Lifting	

Conditions and Hazards the Person  
Can Work In\*

<input type="checkbox"/> Inside	<input type="checkbox"/> Adequate Venti-
<input type="checkbox"/> Outside	<input type="checkbox"/> lation
<input type="checkbox"/> Hot	<input type="checkbox"/> Vibration
<input type="checkbox"/> Cold	<input type="checkbox"/> Mechanical
<input type="checkbox"/> Sudden Temperature	<input type="checkbox"/> Hazards
<input type="checkbox"/> Change	<input type="checkbox"/> Moving Objects
<input type="checkbox"/> Humid	<input type="checkbox"/> Cramped Quarters
<input type="checkbox"/> Dry	<input type="checkbox"/> High Places
<input type="checkbox"/> Wet	<input type="checkbox"/> Exposure to Burns
<input type="checkbox"/> Dusty	<input type="checkbox"/> Electric Hazards
<input type="checkbox"/> Dirty	<input type="checkbox"/> Explosives
<input type="checkbox"/> Odors	<input type="checkbox"/> Radiant Energy
<input type="checkbox"/> Noisy	<input type="checkbox"/> Toxic Conditions
<input type="checkbox"/> Adequate Lighting	<input type="checkbox"/> Working with Others
	<input type="checkbox"/> Working Around Others
	<input type="checkbox"/> Working Alone

\*Blank indicates not present, disability.

"1" indicates the person can perform the characteristic for 0-35% of time or fair ability.

"2" indicates the person can perform the characteristic for 36-100% of time or sound ability.

## APPENDIX C

### DEFINITIONS OF THE TERMS USED ON FORMS

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DEFINITIONS OF THE TERMS<sup>1</sup>  
USED ON FORMS

1. Work Rapidly for Long Periods. Ability to work at high speed during the entire working period. It does not involve consideration of energy output, but simply rate of performance. Working period is the time normally devoted to work activity. It may vary with industries, plants, and processes. An additional characteristic should be used for occupations involving "the ability to work rapidly for short periods."

Considerations are: pacing by machine or management; pay incentives; repetitiveness of work; number and complexity of units produced.

2. Strength of Hands. Ability to perform work requiring strong muscles in fingers, hands, wrists, and forearms such as are primarily involved in squeezing, bending, pulling, twisting, snapping, turning, or gripping objects. It does not involve use of arm from elbow to shoulder as a primary muscular activity.

Considerations are: Weights handled; frequency and duration of handling; rapidity of movement; distance objects are moved.

3. Strength of Arms. Ability to perform work requiring strong muscles in the arms from elbow to shoulder, such as are primarily involved in lifting, swinging, pushing, pulling, carrying, or throwing objects.

Considerations are: weights handled; frequency and duration of handling; rapidity of movement; distance objects are moved.

4. Strength of Legs. Ability to perform work requiring strong, well-developed muscles in legs and thighs, ankles, and feet, such as are primarily required in such activities as lifting objects by knee action, operating pedals requiring pressure, gripping or bracing with the knees and legs, or extensive climbing, walking, kneeling, standing or crawling.

Considerations are: weights handled; frequency and duration of handling; rapidity of movement; distance

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<sup>1</sup>Anilkant T. Dalal, "Computer Matching of Worker's Qualifications to Job Requirements" (unpub. Master's Thesis, Mississippi State University, 1969).



objects are moved; extent of climbing; walking, kneeling, standing, or crawling involved.

5. **Strength of Back.** Ability to perform work requiring strong muscles in the back and shoulders such as are primarily involved in such activities as lifting objects from the floor, pushing with back and shoulders, or striking blows with a sledge hammer.

Considerations are: weights handled; frequency and duration of handling; rapidity of movement; distance objects are moved.

6. **Dexterity of Fingers.** Ability to move the fingers, or manipulate objects with the fingers, rapidly or accurately. This is not to be confused with the use of the fingers as part of whole-hand movement.

Considerations are: complexity and speed of movements; fingers of one or both hands used; size of objects handled; accuracy of movements required.

7. **Dexterity of Hands and Arms.** Ability to move hands and arms quickly or accurately.

Considerations are: complexity, frequency, repetitiveness of movements; both hands or one used; accuracy required.

8. **Dexterity of Feet and Legs.** Ability to move the feet and legs rapidly or accurately.

Considerations are: complexity, frequency, repetitiveness of movements; use of both feet or legs, or use of one foot or leg; accuracy necessary.

9. **Eye-hand Coordination.** Ability to control accurately the movements of the hands by what the eyes see. It does not necessarily involve speed.

Considerations are: complexity, frequency, and repetitiveness of movements.

10. **Foot-Hand-Eye Coordination.** Ability to control accurately the simultaneous movements of hands and feet by what the eyes see. This does not necessarily involve speed. Eye-hand coordination should always be rated when this item is rated. Foot-eye coordination (not involving the hands), foot-hand coordination (not involving the eyes), and leg-hand-eye coordination (not involving the feet) should be entered as additional characteristics.

Considerations are: rapidity, complexity, and frequency of movements.

11. Coordination of Independent Movements of Both Hands. Ability to move the right and left hands independently and at the same time; doing one thing with one hand while doing something else with the other hand. Does not necessarily involve vision.

Considerations are: rapidity, frequency, and complexity of movements; direction of movements; difference between movements of the two hands.

12. Estimate Size of Objects. Ability to make accurate judgments of dimensions such as length, breadth, depth, height, or thickness, or to estimate general over-all size or area. Mechanical aids may be used for determining bases for arriving at final estimate. Special senses and discriminations (such as vision, hearing, touch discrimination, etc.) used in arriving at estimations of size should be rated in addition when this item is rated. Estimation of distance, except when part of the estimation of speed of moving objects (no. 15), should be entered as an additional characteristic.

Considerations are: complexity of objects; number of dimensions considered; variability of estimations required; frequency and rapidity of estimations made; extent to which mechanical aids are used.

13. Estimate Quantity of Objects. Ability to make accurate judgments of quantity or capacity of objects in terms of weight, number or volume. Mechanical aids may be used for determining bases for arriving at final estimate. Special senses or discriminations (such as vision, muscular discrimination, etc.) used in arriving at estimations of quantity should be rated in addition when this item is rated.

Considerations are: variability of estimations required; complexity of objects; frequency and rapidity of estimations required; extent to which mechanical aids are used.

14. Perceive Forms of Objects. Ability to distinguish whether objects are of the correct shape or outline, or to conceive generally in terms of shape. Mechanical aids may be used for determining bases for arriving at final estimate. Includes ability to perceive spatial relations. Special senses, estimations, or discriminations (such as vision, touch discrimination,

etc.) used in the perception of form, should be rated in addition when this item is rated.

Considerations are: complexity of form; rapidity and frequency of perceptions required; comparisons with concrete standard or a mental concept of standard; extent to which mechanical aids are used.

15. Estimate Speed of Moving Objects. Ability to make accurate judgments of the rate of motion of a moving object in relation to other moving objects or to a fixed point. Mechanical aids may be used for determining bases for arriving at final estimate. The estimation of speed involves the estimation of both time and distance. When so involved, these characteristics should not be rated separately. However, if the estimation of either time or distance, not in relation to speed, is involved in an occupation, an additional characteristic should be used.

Considerations are: frequency, rapidity, and complexity of estimations; variability of estimations required; extent to which mechanical aids are used.

16. Memory for Details (Things). Ability to remember or recall concrete details, such as size, color, price, quantity, order of complex assembly, job specification items, etc. This is distinguished from memory for ideas (no. 17) which involves ability to remember theory behind concrete facts.

Considerations are: number and complexity of items remembered; length of time items must be remembered; frequency and rapidity of memory changes required.

17. Memory for Ideas (Abstract). Ability to remember principles, ideas, or theories behind a job, including memory for plans, policies, processes, etc. It is distinguished from ability to remember details (no. 16) which merely involves remembering concrete items.

Considerations are: complexity of job; frequency of changes in job situation; length of time remembered.

18. Memory for Oral Directions. Ability to remember a series of directions or other information given orally.

Considerations are: length of time remembered; complexity of material remembered; frequency and rapidity of changes in content of material to be remembered.

19. Understanding of Mechanical Devices. Ability to comprehend and put into use the principles of mechanical

structure and operation; mechanical insight or ingenuity. This refers to problem-solving ability applied to machines, equipment, apparatus, tools, and other devices used in industry. Understanding general structural principles and methods, not concerning machines, should be rated as an additional characteristic.

Considerations are: number and variety of principles involved; complexity of devices involved; direct application of theory and construction, or creative use in design.

20. Attention to Many Items. Ability to keep the mind on many parts of a job at one time, or to shift the attention from one thing to another readily. This is not to be confused with memory for details. Memory for details concerns the ability to remember or recall items. Attention to items, although it may also involve memory for those items, should be considered solely in terms of application of attention.

Considerations are: complexity and accuracy of job and number of items; frequency and rapidity of shifts of attention required; working conditions affecting attention.

21. Skill in Written Expression. Ability to present information or ideas clearly in writing. Do not confine this rating to creative writing only, but rate this item for any job involving the development of written material.

Considerations are: nature and purpose of written material; classes of persons receiving it; responsibility and accuracy of job.

22. Tact in Dealing With People. Ability to use diplomacy in human relations of any sort so as to obtain or retain respect, good will, cooperation, etc. This should be used for rating jobs involving either public contact work or personnel work within a plant. Do not confuse with general liability to meet and deal with people. Do not confuse with general liability to meet and deal with people, involving tact at times. Reserve "tact" for the rating of ability to handle "ticklish" situations in dealing with people.

Considerations are: frequency of situations requiring tactful handling; responsibility of job; consequences of actions.

23. Keenness of Vision. Ability to perceive or recognize objects, or locate points at a distance, or to make

accurate discriminations through the use of vision. Any estimations or perceptions (such as of form, size, etc.) arrived at by the use of keen vision should be rated in addition when this item is rated. Consideration should be made as to acceptability of use of aids.

Considerations are: fineness of distinctions required; frequency, rapidity and complexity of discrimination involved; conditions of work; aids to vision used.

24. Sense of Smell. Ability to distinguish similarities or differences in the intensity or quality of odors, or to recognize a particular odor. Any of the estimations arrived at by the use of the sense of smell should be rated in addition when this item is rated.

Considerations are: fineness of distinctions required; frequency and rapidity of odor identification; intensity of odors dealt with.

25. Sense of Taste. Ability to distinguish accurately differences or similarities in the intensity or quality of tastes, or to recognize a particular taste. Any estimations arrived at through the sense of taste should be rated in addition when this item is rated.

Considerations are: fineness of distinctions required; intensity and complexity of tastes dealt with; frequency and rapidity of tasting.

26. Touch Discrimination. Ability to judge accurately through the use of touch; sensitivity of fingers or other parts of body to smoothness, roughness, contour, and other surface qualities of objects. This does not involve pressure sense. It does not include estimation of temperature or moisture by touch. These should be rated as additional characteristics where necessary. Any estimations or perceptions (such as form, quality, etc.) arrived at by the use of touch discrimination should be rated in addition when this item is rated.

Considerations are: frequency, rapidity, and complexity of discriminations; fineness of distinctions required.

27. Intelligence. Ability to reason and make judgments. Intelligence is an over-all term referring to problem-solving ability and involving reasoning, judgment, memory, attention, alertness, versatility, inventiveness, etc. This characteristic should be rated in addition to other characteristics which may be incidental to problem-solving ability such as ability to plan, ability to make decisions, adaptability, etc.

Considerations are: complexity of problems; responsibility of job.

28. Adaptability. Ability to adjust readily to new and changing situations in the job. A sum-total of physical, temperamental, and intellectual flexibility. Not to be confused with emotional stability, intelligence, initiative or attention to many items.

Considerations are: complexity of job; frequency and rapidity of changes in job details; speed with which adjustment is required.

29. Ability to Plan. Ability to recognize and comprehend what things are to be done to achieve a specific end, and to decide upon, set up, and coordinate procedures for attaining that result; ability to organize ideas or things.

Considerations are: complexity of problems met; responsibility of job; variability of work situation.

30. Initiative. Ability to recognize the implications of a work situation and to act upon the needs of the situation without specific instructions.

Considerations are: complexity, responsibility, and variability of work; consequences of actions.

31. Oral Expression. Ability to express one's self orally in a clear and effective manner. Any activity requiring spoken words should be considered for rating under this characteristic, and its use should not be considered for rating under this characteristic, and its use should not be limited to sales work, lecturing, etc.

Considerations are: responsibility of job and consequences of spoken words, whether directly before audience or through mechanical reproduction; purpose of spoken words.

32. Height. Specific requirement of height within fairly definite limits due to elements performed on the job. Do not consider this item as the height requirements stated by employers, but rate it only in light of work done elements placing definite height requirements upon the worker.

33. Weight. Specific requirement of weight within fairly definite limits, due to elements performed on the job. Do not consider this item as the weight requirements stated by employers, but rate it only in the light of

work done elements placing definite weight requirements upon the worker.

34. Muscular Discrimination. Ability to make judgments on the basis of muscular sensitivity, such as is required in estimating weight by lifting, in estimating resistance by pushing or pulling, in sensing position of or guiding body members without using eyes, or in regulating pressure of body members as in the use of pedals, hammering, etc. Estimation made through the use of muscular discrimination should be always rated in addition when this item is rated.

Considerations are: frequency, rapidity, complexity of discriminations required; fineness of distinctions necessary.

35. Arithmetic Computation. Ability to do arithmetic or higher mathematics. Occupations which involve analysis or interpretation of quantitative statistical data, but which do not actually involve arithmetic computation should also be rated for this item.

Considerations are: accuracy and rapidity of arithmetic calculation required; calculation aids used; level of mathematics involved.

36. Ability to Make Decisions. Ability to consider the evidence and reach some conclusion without undue delay.

Considerations are: complexity of evidence; frequency and rapidity of decisions required; variation in job situation; responsibility of job and consequences of decisions.

37. Memory of Names and Persons. Ability to recognize or recall names or persons by means of appearance, voice, or other information known about them. Rate the item for any job in which identification of people by name is required.

Considerations are: numbers of persons to be remembered; amount of direct contact assisting in memory; type of information assisting in memory; responsibility of job.

38. Personal Appearance. Personal looks, grooming, attire, neatness, or attractiveness. Rate for any job in which some factor of personal appearance is involved in the work.

Considerations are: consequence and significance of personal appearance on the job.

39. Concentration Amidst Distractions. Ability to carry on a job amidst noise, interruptions, or other disturbing influences. Do not confuse with attention to many items, although distractions may be a contributing factor to the rating of attention.

Considerations are: complexity of job; type and degree of distraction; responsibility of work; and accuracy required.

40. Emotional Stability. Ability to remain calm and self-controlled under all conditions.

Considerations are: consequences of actions, and responsibility and accuracy of job; frequency and rapidity of situation adjustments necessary.

41. Work Under Hazardous Conditions. Ability to carry on work under conditions of hazard which may result in physical injury. Do not confuse with emotional stability, but rate as a separate factor.

Considerations are: extent of injury possible or probable; safety measures operating; responsibility of job; effect of actions on other workers.

42. Estimate Quality of Objects. Ability to judge the quality of workmanship or of material. Since the estimation of quality usually involves the application of one of the special senses, or the ability to make estimations and discriminations of a more specific nature, rate all such related items in addition to this characteristic.

Considerations are: responsibility, complexity and accuracy of job; finality of judgment made; frequency and rapidity of judgments required.

43. Work Under Unpleasant Physical Conditions. Ability to work on job under conditions affecting physical comfort. Qualify each rating of this item. Do not consider possibility of becoming accustomed to unpleasantness when rating this item. Unpleasant physical conditions or surroundings include bad odors, noise, vibration, dust, dirt, fumes, wetness, humidity, extreme heat or cold, wide temperature variation, exposure to acids, unpleasant sights, etc.

44. Ability to Meet and Deal With the Public. Ability to meet and deal with the public, and to establish and maintain agreeable relations. This includes face-to-face, telephonic or other contacts with the public.



It does not include factors involved in "tact in dealing with people." (no. 22).

#### Definitions of Physical Activities

45. Walking: Moving about on the feet by taking alternate steps, setting one foot before the other without running.
46. Jumping: Projecting the body up, down, or horizontally through the air, primarily by the muscular action of the feet and legs.
47. Running: Moving rapidly by using the feet and legs more quickly than in walking.
48. Balancing: Walking, standing, or running on narrow or slippery elevated surfaces by maintaining body equilibrium to prevent falling.
49. Climbing: Ascending or descending ladders, stairs, scaffolding, ramps, poles, ropes, and the like, using the feet and legs or using hands and arms as well.
50. Crawling: Moving about on the hands and knees or hands and feet.
51. Standing: Supporting oneself on the feet and legs in an upright or nearly upright position.
52. Turning: Twisting partly around from a stationary standing or sitting position, usually involving the spine, trunk, neck and legs.
53. Stooping: Bending the body downward and forward by bending the spine at the waist; not crouching.
54. Crouching: Bending the body downward and forward by bending the legs and spine; not stooping.
55. Kneeling: Bending the legs at the knees to come to rest on the knee or knees.
56. Sitting: Resting upon the haunches or lower or posterior extremities of the trunk as in occupying a bench, chair, saddle, etc.
57. Reaching: Extending the hands and arms in any direction.

58. Lifting: Raising or lowering an object from one level to another; includes upward pulling.
59. Carrying: Transporting an object, usually by holding it in the hands and arms.
60. Throwing: Propelling an object through space by swinging motion of the hand and arm with or without the use of tongs or other devices.
61. Pushing: Exerting force upon an object so that the object moves away from the force, including slapping, striking, kicking, and treadle actions.
62. Pulling: Exerting force upon an object so that the object moves toward the force, including jerking.
63. Handling: Seizing, holding, grasping, turning, or otherwise working with the hand or hands; not fingering.
64. Fingering: Picking, pinching, or otherwise working with the fingers primarily, (rather than with the whole hand or arm, as in handling).
65. Feeling: Perceiving such attributes of objects as size, shape, temperature or texture, by means of receptors in the skin, typically those of the finger tips.
66. Talking: Expressing or exchanging ideas by means of spoken word.
67. Hearing: Perceiving the nature of sounds by the ear.
68. Seeing: Perceiving the nature of objects by the eye.
69. Color Vision: Perceiving the color of objects by sight.
70. Depth Perception: Perceiving relative or absolute distances of an object from the observer or from one object to another.
71. Working Speed: The rate of speed the job requires of the worker. This item is checked with an "x" only where the job requires significantly high rates of working speed.

#### Definitions of Working Conditions

72. Inside: Indoor protection from weather conditions.

73. Outside: Out of doors, or under an overhead covering with slight protection from the weather.
74. Hot: Temperature sufficiently high to cause perceptible bodily discomfort.
75. Cold: Temperature sufficiently low to cause perceptible bodily discomfort.
76. Sudden Temperature Changes: Variations in temperature which are sufficiently marked and abrupt to cause perceptible bodily reactions.
77. Humid: Atmospheric condition with moisture content sufficiently high to cause perceptible bodily discomfort.
78. Dry: Atmospheric condition with moisture content sufficiently low to cause perceptible bodily discomfort.
79. Wet: Contact with water or other liquids.
80. Dusty: Air filled with small particles of any kind such as textile dust, flour, wood, leather, feathers, etc., and inorganic dust including silica and asbestos, which make the workplace unpleasant or are the source of occupational diseases.
81. Dirty: Contact with or exposure to dirt, litter, soiled materials, etc.
82. Odors: Perceptible smells, either toxic or nontoxic.
83. Noisy: Sufficient sound to cause thought distraction or possible injury to the sense of hearing.
84. Adequate Lighting: Sufficient lighting to minimize eye strain. (A zero before this item would indicate the lighting is either insufficient or excessive.)
85. Adequate Ventilation: Sufficient ventilation to cause neither a feeling of suffocation nor exposure to drafts. (A zero before this item would indicate that the ventilation is insufficient or excessive.)
86. Vibration: Production of an oscillating or quivering movement of the body or strain on the muscles, particularly of the legs and arms, as from repeated motion, pressure, or shock.
87. Mechanical Hazards: Exposure to materials or mechanical parts involving the risk of bodily injury.

88. Moving Objects: Exposure to moving equipment and objects such as overhead cranes, hand and motor driven vehicles, falling objects, etc., which involve the risk of bodily injury; also the act of operating such equipment.
89. Cramped Quarters: Workplace where freedom of movement is restricted or where worker cannot maintain an upright position.
90. High Places: Workplace at an elevation above the floor or ground level from which it is possible to fall and be injured.
91. Exposure to Burns: Workplace involving the risk of being burned from hot materials, fire or chemical agents.
92. Electrical Hazards: Exposure to high-tension wires, transformers, bus-bars, or other uninsulated or unshielded electrical equipment which involve the risk of electric shock.
93. Explosives: Exposure to explosive gases, vapors, dusts, liquids, and substances which involve the risk of bodily injury.
94. Radiant Energy: Exposure to radio-active substances (radium, uranium, thorium, etc.), X-Rays, ultraviolet rays, or infra-red rays, which involve the risk of impairment of sight or general or localized disabling conditions.
95. Toxic Conditions: Exposure to toxic dusts, fumes, gases, vapors, mists, or liquids which cause general or localized disabling conditions as a result of inhalation or action on the skin.
96. Working With Others: Job requires occupational cooperation with fellow workers, or direct contact with the public.
97. Working Around Others: Job requires independent occupational effort but in proximity to fellow workers or the public.
98. Working Alone: Job requires independent occupational effort and virtually no contact with fellow workers or the public.

APPENDIX D

MODIFIED JOB REQUIREMENTS FORM

## JOB REQUIREMENTS

Job Title \_\_\_\_\_ Firm \_\_\_\_\_

Can work be done by both sexes: Y N

If "No" answered above, which sex is required? M F

If "Yes" answered above, which sex is preferred? M F

## Worker Characteristics Required

Rank*	Characteristic	Required Level**
_____	1. Work rapidly for long periods . . . .	_____
_____	2. Strength of hands . . . .	_____
_____	3. Strength of arms . . . .	_____
_____	4. Strength of legs . . . .	_____
_____	5. Strength of back . . . .	_____
_____	6. Dexterity of fingers . . . .	_____
_____	7. Dexterity of hands and arms . . . .	_____
_____	8. Dexterity of foot and leg . . . .	_____
_____	9. Eye-hand coordination . . . .	_____
_____	10. Foot-eye-hand coordination . . . .	_____
_____	11. Coordination, both hands . . . .	_____
_____	12. Estimate size of objects . . . .	_____
_____	13. Estimate quantity of objects . . . .	_____
_____	14. Perceive form of objects . . . .	_____
_____	15. Estimate speed of moving objects . . . .	_____
_____	16. Memory for details (things) . . . .	_____
_____	17. Memory for ideas (abstract) . . . .	_____
_____	18. Memory for oral directions . . . .	_____
_____	19. Understanding mechanical devices . . . .	_____
_____	20. Attention to many items . . . .	_____
_____	21. Skill in written experience . . . .	_____
_____	22. Tact in dealing with people . . . .	_____
_____	23. Keeness of vision . . . .	_____
_____	24. Sense of smell . . . .	_____
_____	25. Sense of taste . . . .	_____
_____	26. Touch discrimination . . . .	_____
_____	27. Intelligence . . . .	_____
_____	28. Adaptability . . . .	_____
_____	29. Ability to plan . . . .	_____
_____	30. Initiative . . . .	_____
_____	31. Oral expression . . . .	_____
_____	32. Height . . . .	_____
_____	33. Weight . . . .	_____
_____	34. Muscular discrimination . . . .	_____
_____	35. Arithmetic computation . . . .	_____
_____	36. Ability to make decisions . . . .	_____

Rank*	Characteristic	Required Level**
_____	37. Memory for names and persons . . . .	_____
_____	38. Personal appearance . . . .	_____
_____	39. Concentration amidst distractions . .	_____
_____	40. Emotional stability . . . .	_____
_____	41. Work under hazardous conditions . . .	_____
_____	42. Estimate quality of objects . . . .	_____
_____	43. Unpleasant physical conditions . . . .	_____
_____	44. Ability to meet and deal with the public	_____

#### Required Physical Activities

_____	45. Walking . . . . .	_____
_____	46. Jumping . . . . .	_____
_____	47. Running . . . . .	_____
_____	48. Balancing . . . . .	_____
_____	49. Climbing . . . . .	_____
_____	50. Crawling . . . . .	_____
_____	51. Standing . . . . .	_____
_____	52. Turning . . . . .	_____
_____	53. Stooping . . . . .	_____
_____	54. Crouching . . . . .	_____
_____	55. Kneeling . . . . .	_____
_____	56. Sitting . . . . .	_____
_____	57. Reaching . . . . .	_____
_____	58. Lifting . . . . .	_____
_____	59. Carrying . . . . .	_____
_____	60. Throwing . . . . .	_____
_____	61. Pushing . . . . .	_____
_____	62. Pulling . . . . .	_____
_____	63. Handling . . . . .	_____
_____	64. Fingering . . . . .	_____
_____	65. Feeling . . . . .	_____
_____	66. Talking . . . . .	_____
_____	67. Hearing . . . . .	_____
_____	68. Seeing . . . . .	_____
_____	69. Color vision . . . . .	_____
_____	70. Depth perception . . . . .	_____
_____	71. Working speed . . . . .	_____

#### Working Conditions and Hazards Involved

_____	72. Inside . . . . .	_____
_____	73. Outside . . . . .	_____
_____	74. Hot . . . . .	_____
_____	75. Cold . . . . .	_____
_____	76. Sudden temperature change . . . . .	_____
_____	77. Humid . . . . .	_____

Rank*	Conditions and Hazards Involved												Level**
_____	78.	Dry	.	.	.	.	.	.	.	.	.	.	_____
_____	79.	Wet	.	.	.	.	.	.	.	.	.	.	_____
_____	80.	Dusty	.	.	.	.	.	.	.	.	.	.	_____
_____	81.	Dirty	.	.	.	.	.	.	.	.	.	.	_____
_____	82.	Odors	.	.	.	.	.	.	.	.	.	.	_____
_____	83.	Noisy	.	.	.	.	.	.	.	.	.	.	_____
_____	84.	Adequate lighting	.	.	.	.	.	.	.	.	.	.	_____
_____	85.	Adequate ventilation	.	.	.	.	.	.	.	.	.	.	_____
_____	86.	Vibration	.	.	.	.	.	.	.	.	.	.	_____
_____	87.	Mechanical hazards	.	.	.	.	.	.	.	.	.	.	_____
_____	88.	Moving objects	.	.	.	.	.	.	.	.	.	.	_____
_____	89.	Cramped quarters	.	.	.	.	.	.	.	.	.	.	_____
_____	90.	High places	.	.	.	.	.	.	.	.	.	.	_____
_____	91.	Exposure to burns	.	.	.	.	.	.	.	.	.	.	_____
_____	92.	Electric hazards	.	.	.	.	.	.	.	.	.	.	_____
_____	93.	Explosives	.	.	.	.	.	.	.	.	.	.	_____
_____	94.	Radiant energy	.	.	.	.	.	.	.	.	.	.	_____
_____	95.	Toxic conditions	.	.	.	.	.	.	.	.	.	.	_____
_____	96.	Working with others	.	.	.	.	.	.	.	.	.	.	_____
_____	97.	Working around others	.	.	.	.	.	.	.	.	.	.	_____
_____	98.	Working alone	.	.	.	.	.	.	.	.	.	.	_____

\* Rank:

Used to indicate the order of importance among the various characteristics, activities and conditions-hazards which have been assigned a Required Level of "1" or "2". The most important item is to be ranked with a "1". Ranking should continue in a sequential manner through all items having a non-zero Required Level. For example, if fifty of the listed items are considered to be a part of the job (assigned a non-zero Required Level), then those fifty items would be ranked 1 through 50.

\*\* Level:

"0" or blank indicates not present, not a factor, not required.

"1" indicates presence in job, 0 - 35% of time, some requirement, fairly important.

"2" indicates important factor in job, 36 - 100% of time, major requirement, very important.



APPENDIX E

MODIFIED PHYSICAL QUALIFICATIONS FORM

## PHYSICAL QUALIFICATIONS

Name \_\_\_\_\_ Sex \_\_\_\_\_  
 Social Security Number \_\_\_\_\_ - \_\_\_\_\_ Age \_\_\_\_\_

## Individual Characteristics

Characteristic	Level*
1. Work rapidly for long periods . . . . .	_____
2. Strength of hands . . . . .	_____
3. Strength of arms . . . . .	_____
4. Strength of legs . . . . .	_____
5. Strength of back . . . . .	_____
6. Dexterity of fingers . . . . .	_____
7. Dexterity of hands and arms . . . . .	_____
8. Dexterity of foot and leg . . . . .	_____
9. Eye-hand coordination . . . . .	_____
10. Foot-eye-hand coordination . . . . .	_____
11. Coordination, both hands . . . . .	_____
12. Estimate size of objects . . . . .	_____
13. Estimate quantity of objects . . . . .	_____
14. Perceive form of objects . . . . .	_____
15. Estimate speed of moving objects . . . . .	_____
16. Memory for details (things) . . . . .	_____
17. Memory for ideas (abstract) . . . . .	_____
18. Memory for oral directions . . . . .	_____
19. Understanding mechanical devices . . . . .	_____
20. Attention to many items . . . . .	_____
21. Skill in written experience . . . . .	_____
22. Tact in dealing with people . . . . .	_____
23. Keenness of vision . . . . .	_____
24. Sense of smell . . . . .	_____
25. Sense of taste . . . . .	_____
26. Touch discrimination . . . . .	_____
27. Intelligence . . . . .	_____
28. Adaptability . . . . .	_____
29. Ability to plan . . . . .	_____
30. Initiative . . . . .	_____
31. Oral expression . . . . .	_____
32. Height . . . . .	_____
33. Weight . . . . .	_____
34. Muscular discrimination . . . . .	_____
35. Arithmetic computation . . . . .	_____
36. Ability to make decisions . . . . .	_____
37. Memory for names and persons . . . . .	_____
38. Personal appearance . . . . .	_____
39. Concentration amidst distractions . . . . .	_____
40. Emotional stability . . . . .	_____

Characteristic	Level*
41. Work under hazardous conditions . . . . .	_____
42. Estimate quality of objects . . . . .	_____
43. Unpleasant physical conditions . . . . .	_____
44. Ability to meet and deal with the public . . . . .	_____

#### Performable Physical Activities

45. Walking . . . . .	_____
46. Jumping . . . . .	_____
47. Running . . . . .	_____
48. Balancing . . . . .	_____
49. Climbing . . . . .	_____
50. Crawling . . . . .	_____
51. Standing . . . . .	_____
52. Turning . . . . .	_____
53. Stooping . . . . .	_____
54. Crouching . . . . .	_____
55. Kneeling . . . . .	_____
56. Sitting . . . . .	_____
57. Reaching . . . . .	_____
58. Lifting . . . . .	_____
59. Carrying . . . . .	_____
60. Throwing . . . . .	_____
61. Pushing . . . . .	_____
62. Pulling . . . . .	_____
63. Handling . . . . .	_____
64. Fingering . . . . .	_____
65. Feeling . . . . .	_____
66. Talking . . . . .	_____
67. Hearing . . . . .	_____
68. Seeing . . . . .	_____
69. Color vision . . . . .	_____
70. Depth perception . . . . .	_____
71. Working speed . . . . .	_____

#### Tolerable Working Conditions and Hazards

72. Inside . . . . .	_____
73. Outside . . . . .	_____
74. Hot . . . . .	_____
75. Cold . . . . .	_____
76. Sudden Temperature Change . . . . .	_____
77. Humid . . . . .	_____
78. Dry . . . . .	_____
79. Wet . . . . .	_____
80. Dusty . . . . .	_____

Tolerable Conditions and Hazards															Level*
81.	Dirty	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
82.	Odors	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
83.	Noisy	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
84.	Adequate lighting	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
85.	Adequate ventilation	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
86.	Vibration	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
87.	Mechanical hazards	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
88.	Moving objects	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
89.	Cramped quarters	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
90.	High places	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
91.	Exposure to burns	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
92.	Electric hazards	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
93.	Explosives	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
94.	Radiant energy	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
95.	Toxic conditions	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
96.	Working with others	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
97.	Working around others	.	.	.	.	.	.	.	.	.	.	.	.	.	_____
98.	Working alone	.	.	.	.	.	.	.	.	.	.	.	.	.	_____

\* Level

"0" or blank indicates not present, disability.

"1" indicates the person can perform the characteristic for 0 - 35% of time or fair ability.

"2" indicates the person can perform the characteristic for 36 - 100% of the time or sound ability.

## APPENDIX F

### SOURCE COMPUTER PROGRAM

NONPARAMETRIC MULTIVARIANT ATTRIBUTE RETRIEVAL

BRUCE E. HERRING

DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT  
OKLAHOMA STATE UNIVERSITY  
JANUARY 1972

THIS PROGRAM IS DESIGNED TO PERFORM THE JOB  
APPLICANT FILE SCREENING PROCEDURE DESCRIBED IN  
CHAPTER III.

```

      INTEGER JOB(100),APPL(50,100),NA,ORDER(100),ENTRY(21),
1  RANK,EXTRA,NAME(50,4),SOCS(50),TITLE(8),JOB(3),
2  CODE(3),WHO(10,4),SEX(50),DSEX,RSEX,PSEX,SAVSEX(10),
3  AA,BB,CC,BLANK,SCS,Y,LESS,TBL(5,10),BSTPOR(10,10,2),
4  BETBAD(10,2)
      REAL ALPHA,WEIGHT(100),RESULT(10),SCORE
      DATA BLANK/'      '/,Y/'Y'/
      NA=0
1  NA=NA+1

```

READ A CARD CONTAINING APPLICANT'S IDENTIFICATION AND  
PART OF THE QUALIFICATIONS.

```

      READ(5,2),SOCS(NA),(NAME(NA,J),J=1,4),SEX(NA),
1  (APPL(NA,J),J=1,38)
2  FORMAT(I9,4A4,16X,A1,38I1)
      IF(SOCS(NA)-999999999)8,5,8

```

READ A CARD CONTAINING REMAINDER OF APPLICANT'S  
QUALIFICATIONS.

```

8  READ(5,3)SCS,(APPL(NA,J),J=39,100)
3  FORMAT(I9,62I1)
      GO TO 1

```

NA REPRESENTS THE NUMBER OF APPLICANTS UNDER CONSIDER-  
ATION.

```

      NA=NA-1

```

THE NEXT ELEVEN STATEMENTS CLEAR VARIOUS ARRAYS.

```

21 DO 81 IJ=1,100
      JOB(IJ)=0
81 ORDER(IJ)=0
      DO 50 I=1,10
          RESULT(I)=0.

```

```

      DO 70 J=1,5
70  TBL(J,I)=0
      SAVSEX(I)=BLANK
      DO 95 J=1,10
      DO 95 K=1,2
95  BSTPOR(I,J,K)=0
      DO 50 J=1,4
50  WHO(I,J)=BLANK
C
C  READ THE JOB IDENTIFICATION CARD.
C
      READ(5,15)TITLE,DSEX,RSEX,PSEX,IQUIT
15  FORMAT(8A4,3A1,44X,I1)
      IF(IQUIT-9)14,999,14
14  RANK=0
C
C  READ A JOB CHARACTERISTICS (ATTRIBUTES) CARD.
C
      READ(5,9)JOB CD,ALPHA,(ENTRY(J),J=1,21)
      9  FORMAT(3A4,F5.0,21I3)
141 DO 10 K=1,19,3
      L=K+1
      M=K+2
C
C  CHECK FOR BLANK ENTRIES.
C
      DO 11 N=K,L
      IF(ENTRY(N))10,10,11
11  CONTINUE
      I=ENTRY(K)
      J=ENTRY(L)
C
C  CHECK FOR MULTIPLE ITEMS WITH SAME RANK.
C
      IF(ORDER(I))12,12,10
C
C  ATTRIBUTE NUMBER STORED IN THE RANK POSITION ELEMENT
C  OF THE ORDER ARRAY.
C
12  ORDER(I)=J
      JOB(J)=ENTRY(M)
      IF(I-RANK)10,10,16
16  RANK=I
10  CONTINUE
C
C  READ A JOB CHARACTERISTICS (ATTRIBUTES) CARD.
C
      READ(5,13)CODE,(ENTRY(J),J=1,21)
13  FORMAT(3A4,21I3)
      IF(JOB CD(1).EQ.CODE(1).AND.JOB CD(2).EQ.CODE(2).AND.
1  JOB CD(3).EQ.CODE(3))GO TO 141
C
C  CALCULATION OF EXPONENTIAL WEIGHTING FACTORS.

```

```

C
  20 WGT=1-ALPHA
      DO 22 I=1,RANK
  22 WEIGHT(I)=ALPHA*WGT**I
C
C THIS STATEMENT REPRESENTS THE BEGINNING OF THE LOOP
C WHICH CONTROL THE CHECKING OF ALL APPLICANT RECORDS.
C
      DO 23 I=1,NA
C
C THE NEXT FIVE STATEMENTS CLEAR STORAGE ARRAYS.
C
      DO 90 J=1,10
      DO 90 K=1,2
  90 BETBAD(J,K)=0
      EXTRA=0
      LESS=0
C
C THE NEXT NINE STATEMENTS CHECK THE SEX REQUIREMENTS.
C
      IF(DSEX.NE.Y)GO TO 51
      IF(PSEX.EQ.SEX(I))GO TO 52
      GO TO 53
  52 SCORE=ALPHA
      GO TO 54
  51 CONTINUE
      IF(RSEX.EQ.SEX(I))GO TO 52
      GO TO 23
  53 SCORE=0.
C
C THE NEXT TWELVE STATEMENTS CHECK TO SEE WHETHER THE
C APPLICANT'S ATTRIBUTES ARE GREATER THAN, LESS THAN, OR
C EQUAL TO STATED NEEDS. NOT EQUAL ATTRIBUTES ARE
C RECORDED FOR LATER PRINTING.
C
  54 DO 224 J=1,RANK
      K=ORDER(J)
      IF(APPL(I,K)-JOB(K))24,31,32
  32 EXTRA=EXTRA+1
      IF(EXTRA.GT.10)GO TO 31
      BETBAD(EXTRA,1)=K
  31 SCORE=SCORE+WEIGHT(J)
      GO TO 224
  24 LESS=LESS+1
      IF(LESS.GT.10)GO TO 224
      BETBAD(LESS,2)=K
  224 CONTINUE
      SCORE=SCORE*100.
      DO 25 II=1,10
      JJ=II
C
C THIS LOOKS FOR THE PROPER PUSHDOWN STORAGE POSITION
C FOR HOLDING INFORMATION ON THE CURRENT APPLICANT.

```



C

```

      IF (RESULT (II) - SCORE) 26, 25, 25
25  CONTINUE
      GO TO 23
26  IF (JJ.GE.10) GO TO 83

```

C

```

C  THE NEXT THIRTY-ONE STATEMENTS ARE UTILIZED FOR
C  RECORDING CURRENT APPLICANT INFORMATION IN THE
C  PUSHDOWN STORAGE UNITS.
C

```

C

```

      JK=9+JJ
      DO 82 II=JJ,9
      MN=JK-II
      LN=MN+1
      IF (LN.GE.11) GO TO 83
      SAVSEX (LN)=SAVSEX (MN)
      RESULT (LN)=RESULT (MN)
      DO 72 K=1,5
72  TBL (K,LN)=TBL (K,MN)
      DO 93 LL=1,10
      DO 93 K=1,2
93  BSTPOR (LN,LL,K)=BSTPOR (MN,LL,K)
      DO 29 LL=1,4
29  WHO (LN,LL)=WHO (MN,LL)
82  CONTINUE
83  CONTINUE
      RESULT (JJ)=SCORE
      TBL (5,JJ)=EXTRA
      IF (EXTRA.GT.10) EXTRA=10
      TBL (1,JJ)=EXTRA
      TBL (4,JJ)=LESS
      IF (LESS.GT.10) LESS=10
      TBL (2,JJ)=LESS
      TBL (3,JJ)=SOCS (I)
      SAVSEX (JJ)=SEX (I)
      DO 27 LM=1,4
27  WHO (JJ,LM)=NAME (I,LM)
      DO 91 LM=1,10
      DO 91 K=1,2
91  BSTPOR (JJ,LM,K)=BETBAD (LM,K)
23  CONTINUE
30  WRITE (6,60) TITLE
60  FORMAT (1H1, 'RESULTS OF SEARCH ON JOB OF ', 8A4, '//,
1  54X, 'QUALIFICATIONS', //, 60X, 'VS', //, 54X,
2  'SPECIFICATIONS.', //, 38X, 'SOCIAL', 13X, 'NUMBER OF',
3  5X, 'UP TO TEN SPECIFIC FACTORS WHEREIN')
      WRITE (6,61)
61  FORMAT (1H, 8X, 'MATCH', 23X, 'SECURITY', 9X,
1  'INSTANCES WHERE INDIVIDUALS QUALIFICATIONS',
2  /, 1X, 'RANK      VALUE      NAME', 14X, 'NUMBER', 5X,
3  'SEX BETTER    POORER ARE BETTER', 9X, 'ARE POORER')
      DO 69 N=1,10
      AA=TBL (3,N)/1000000

```

```

      BB=TBL(3,N)/10000
      BB=BB-(AA*100)
      CC=TBL(3,N)-((AA*1000000)+(BB*10000))
      MM=TBL(2,N)
      MB=MM
      NN=TBL(1,N)
      NB=NN
      IF(NN.LE.0)NN=1
      IF(NN.GT.5)NN=5
67  WRITE(6,68)N,RESULT(N),(WHO(N,J),J=1,4),AA,BB,CC,
     1 SAVSEX(N),TBL(5,N),TBL(4,N),(BSTPOR(N,J,1),J=1,NN)
68  FORMAT(1H-,I3,F12.5,2X,4A4,2X,I3,'-',I2,'-',I4,3X,
     1 A1,5X,I2,7X,I2,3X,5I3)
      IF(MM.LE.0)GO TO 691
      IF(MM.GT.5)MM=5
      WRITE(6,63)(BSTPOR(N,J,2),J=1,MM)
63  FORMAT(1H+,88X,5I3)
691 IF(NB.LT.6)GO TO 692
      WRITE(6,650)(BSTPOR(N,J,1),J=6,NB)
650 FORMAT(1H ,70X,5I3)
      GO TO 693
692 WRITE(6,651)
651 FORMAT(1H )
693 IF(MB.LT.6)GO TO 69
      WRITE(6,652)(BSTPOR(N,J,2),J=6,MB)
652 FORMAT(1H+,89X,5I3)
69  CONTINUE
      GO TO 21
999 WRITE(6,96)
96  FORMAT(1H1)
      STOP
      END

```

## APPENDIX G

### APL DESCRIPTION OF PROCEDURE

AR0	$na \leftarrow 0$	
AR1	$na \leftarrow na + 1$	
AR2	[ Read a card containing applicant's identification and part of the qualifications. ]	
AR3	$SOCs^{na} : 999999999$	$= \rightarrow AR5$
AR4	[ Read a card containing remainder of applicant's qualifications. ] $\rightarrow AR1$	
AR5	$na \leftarrow na - 1$	
AR6	$JOB \leftarrow \bar{E}(100)$	
AR7	$ORDER \leftarrow \bar{E}(100)$	
AR8	$RESULT \leftarrow \bar{E}(10)$	
AR9	$TBL \leftarrow \bar{E}(50)$	
AR10	$SAVSEX \leftarrow '' \cdot \epsilon(10)$	
AR11	$i \leftarrow 1$	
AR12	$BSTPOR^i \leftarrow \bar{E}(20)$	
AR13	$i \leftarrow i + 1$	
AR14	$i : 10 \leq$	$\rightarrow AR12$
AR15	$WHO \leftarrow '' \cdot E(100)$	
AR16	Read Job Identification Card	
AR17	$iquit : 9$	$= \rightarrow stop$
AR18	$rank \leftarrow 0$	
AR19	Read Job Characteristics Card	
AR20	$k \leftarrow 1$	
AR21	$l \leftarrow k + 1$	
AR22	$m \leftarrow k + 2$	
AR23	$n \leftarrow k$	

AR24	$ENTRY^n : 0 \leq \rightarrow AR34$
AR25	$n \leftarrow n + 1$
AR26	$n : l \leq \rightarrow AR23$
AR27	$i \leftarrow ENTRY^k$
AR28	$j \leftarrow ENTRY^l$
AR29	$ORDER^i : 0 \neq \rightarrow AR34$
AR30	$ORDER^i \leftarrow j$
AR31	$JOB^j \leftarrow ENTRY^m$
AR32	$i : rank \leq \rightarrow AR34$
AR33	$rank \leftarrow i$
AR34	$k \leftarrow k + 3$
AR35	$k : 19 \leq \rightarrow AR21$
AR36	Read Job Characteristics Card
AR37	$jobcd : code = \rightarrow AR21$
AR38	$wgt \leftarrow 1 - alpha$
AR39	$i \leftarrow 1$
AR40	$WEIGHT^i \leftarrow alpha \cdot wgt * i$
AR41	$i \leftarrow i + 1$
AR42	$i : rank \leq \rightarrow AR40$
AR43	$i \leftarrow 1$
AR44	$BETBAD \leftarrow E(20)$
AR45	$extra \leftarrow 0$
AR46	$less \leftarrow 0$
AR47	$dsex : 'Y' \neq \rightarrow AR50$
AR48	$psex : SEX^i \neq \rightarrow AR51$
AR49	$score \leftarrow alpha \rightarrow AR52$

AR50	$rs_{ex} : SEX^i$	$\neq$	$\rightarrow$	AR117
		$=$	$\rightarrow$	AR52
AR51	$score + 0$			
AR52	$j + 1$			
AR53	$k + ORDER^j$			
AR54	$APPL_j^i : JOB^k$	$<$	$\rightarrow$	AR59
		$=$	$\rightarrow$	AR58
AR55	$extra + extra + 1$			
AR56	$extra : 10$	$>$	$\rightarrow$	AR58
AR57	$BETBAD_1^{extra} + k$			
AR58	$score + score + WEIGHT^j$		$\rightarrow$	AR62
AR59	$less + less + 1$			
AR60	$less : 10$	$>$	$\rightarrow$	AR62
AR61	$BETBAD_2^{less} + k$			
AR62	$j + j + 1$			
AR63	$j : rank$	$\leq$	$\rightarrow$	AR53
AR64	$score + score \cdot 100$			
AR65	$ii + 1$			
AR66	$jj + ii$			
AR67	$RESULT^{ii} : score$	$\leq$	$\rightarrow$	AR70
AR68	$ii + ii + 1$			
AR69	$ii : 10$	$\leq$	$\rightarrow$	AR66
		$>$	$\rightarrow$	AR117
AR70	$jj : 10$	$=$	$\rightarrow$	AR95
AR71	$jk + 9 + jj$			
AR72	$ii + jj$			
AR73	$mn + jk - ii$			
AR74	$ln + mn + 1$			
AR75	$ln : 10$	$>$	$\rightarrow$	AR95

AR76       $\text{SAVSEX}^{\ell n} + \text{SAVSEX}^{mn}$   
 AR77       $\text{RESULT}^{\ell n} + \text{RESULT}^{mn}$   
 AR78       $k + 1$   
 AR79       $\text{TBL}_{\ell n}^k + \text{TBL}_{mn}^k$   
 AR80       $k + k + 1$   
 AR81       $k : 5 \quad \leq \rightarrow \text{AR79}$   
 AR82       $\ell\ell + 1$   
 AR83       $k + 1$   
 AR84       ${}^k\text{BSTPOR}_{\ell\ell}^{\ell n} + {}^k\text{BSTPOR}_{\ell\ell}^{mn}$   
 AR85       $k + k + 1$   
 AR86       $k : 2 \quad \leq \rightarrow \text{AR84}$   
 AR87       $\ell\ell + \ell\ell + 1$   
 AR88       $\ell\ell : 10 \quad \leq \rightarrow \text{AR83}$   
 AR89       $\ell\ell + 1$   
 AR90       $\text{WHO}_{\ell\ell}^{\ell n} + \text{WHO}_{\ell\ell}^{mn}$   
 AR91       $\ell\ell + \ell\ell + 1$   
 AR92       $\ell\ell : 4 \quad \leq \rightarrow \text{AR90}$   
 AR93       $ii + ii + 1$   
 AR94       $ii : 9 \quad \leq \rightarrow \text{AR73}$   
 AR95       $\text{RESULT}^{jj} + \text{score}$   
 AR96       $\text{TBL}_{jj}^5 + \text{extra}$   
 AR97       $\text{extra} : 10 \quad \leq \rightarrow \text{AR99}$   
 AR98       $\text{extra} + 10$   
 AR99       $\text{TBL}_{jj}^1 + \text{extra}$   
 AR100       $\text{TBL}_{jj}^4 + \text{less}$   
 AR101       $\text{less} : 10 \quad \leq \rightarrow \text{AR103}$

AR102  $less + 10$   
 AR103  $TBL_{jj}^2 + less$   
 AR104  $TBL_{jj}^3 + SOCS^i$   
 AR105  $SAVSEX_{jj} + SEX^i$   
 AR106  $lm + 1$   
 AR107  $WHO_{lm}^{jj} + NAME_{lm}^i$   
 AR108  $lm + lm + 1$   
 AR109  $lm : 4 \leq \rightarrow AR107$   
 AR110  $lm + 1$   
 AR111  $k + 1$   
 AR112  $k_{lm}^{BSTPOR_{jj}} + BETBAD_{k}^{lm}$   
 AR113  $k + k + 1$   
 AR114  $k : 2 \leq \rightarrow AR112$   
 AR115  $lm + lm + 1$   
 AR116  $lm : 10 \leq \rightarrow AR111$   
 AR117  $i + i + 1$   
 AR118  $i : na \leq \rightarrow AR44$   
 AR119 Write title and report headings  
 AR120  $n + 1$   
 AR121 Write one of best matches  
 AR122  $n + n + 1$   
 AR123  $n : 10 \begin{matrix} \leq \\ > \end{matrix} \begin{matrix} \rightarrow AR121 \\ \rightarrow AR6 \end{matrix}$



APPENDIX H

INDUSTRIAL SITE SELECTION REQUIREMENTS

## INDUSTRIAL SITE REQUIREMENTS

Requestor \_\_\_\_\_

Address \_\_\_\_\_

Telephone \_\_\_\_\_ Date \_\_\_\_\_

Rank*	Site Characteristics	
_____	1. Acres needed	_____
_____	2. Frontage on waterway	Y N
_____	3. Inside city limits	Y N
_____	4. Zoning	_____
_____	5. Topography - level	Y N
_____	6. Drainage - good	Y N
_____	7. Power at site	Y N
_____	8. Water at site - city	Y N
_____	9. Water at site - well	Y N
_____	10. Water at site - stream	Y N
_____	11. Natural gas at site	Y N
_____	12. Sewerage at site	Y N
_____	13. Highway at site	Y N
_____	14. Paved access road to site	Y N
_____	15. Railway at site	Y N
_____	16. Maximum distance to rail siding	_____
_____	17. Maximum distance to air freight terminal	_____
_____	18. Maximum distance to port facility	_____
_____	19. Maximum cost per acre	_____
_____	20. Minimum size of nearest city	_____

**\*Rank:**

Used to indicate the order of importance among the various characteristics of the site. The most important item is to be ranked with a "1". Ranking should continue in a sequential manner through all items.

## APPENDIX I

### MODIFIED SOURCE COMPUTER PROGRAM

C NONPARAMETRIC MULTIVARIANT ATTRIBUTE RETRIEVAL

C  
C  
C  
C BRUCE E. HERRING

C DEPARTMENT OF INDUSTRIAL ENGINEERING AND MANAGEMENT  
C OKLAHOMA STATE UNIVERSITY  
C JANUARY 1972

C THIS PROGRAM IS DESIGNED TO PERFORM THE  
C INDUSTRIAL SITE AND DWELLING FILE SCREENING  
C PROCEDURES DESCRIBED IN CHAPTER IV.  
C

C  
C INTEGER ATTR(50),CHAR(50,30),NA,ORDER(50),ENTRY(21),  
C 1 RANK,EXTRA,LOCA(50,4),FILE(50),TITLE(8),COAD(3),  
C 2 CODE(3),WHO(10,4),AA,BB,CC,BLANK,LESS,TBL(5,10),  
C 3 BSTPOR(10,10,2),BETBAD(10,2),STYLE(30),FIL  
C REAL ALPHA,WEIGHT(100),RESULT(10)  
C DATA BLANK/' '/

C  
C READ A CARD CONTAINING THE RETRIEVAL STYLE FOR EACH  
C ATTRIBUTE - WHERE A 1 MEANS BINARY (AS YES/NO OR  
C EQUAL/NOT EQUAL), A 2 MEANS GREATER THAN OR EQUAL, AND  
C A 3 MEANS LESS THAN OR EQUAL.  
C

C  
C READ(5,200)(STYLE(J),J=1,30)  
C 200 FORMAT(30I1)  
C NA=0  
C 1 NA=NA+1

C  
C READ A CARD CONTAINING ENTITY'S IDENTIFICATION AND PART  
C OF THE CHARACTERISTICS.  
C

C  
C READ(5,2)FILE(NA),(LOCA(NA,J),J=1,4),(CHAR(NA,J),J=  
C 1 1,11)  
C 2 FORMAT(I9,4A4,11I5)  
C IF(FILE(NA)-999999999)8,5,8

C  
C READ CARDS CONTAINING REMAINDER OF ENTITY'S CHARACTER-  
C ISTICS.  
C

C  
C 8 READ(5,3)FIL,(CHAR(NA,J),J=12,25)  
C 3 FORMAT(I9,1X,14I5)  
C READ(5,3)FIL,(CHAR(NA,J),J=26,30)  
C GO TO 1

C  
C NA REPRESENTS THE NUMBER OF AREAS UNDER CONSIDERATION.  
C

C 5 NA=NA-1

```

C
C THE NEXT TEN STATEMENTS CLEAR THE VARIOUS ARRAYS.
C
21 DO 81 IJ=1,50
    ATTR(IJ)=0
81 ORDER(IJ)=0
    DO 50 I=1,10
        RESULT(I)=0
    DO 70 J=1,5
70 TBL(J,I)=0
    DO 95 J=1,10
    DO 95 K=1,2
95 BSTPOR(I,J,K)=0
    DO 50 J=1,4
50 WHO(I,J)=BLANK
C
C READ THE REQUEST IDENTIFICATION CARD.
C
    READ(5,15)TITLE,IQUIT
15 FORMAT(8A4,47X,I1)
    IF(IQUIT-9)14,999,14
14 RANK=0
C
C READ A REQUEST CHARACTERISTICS (ATTRIBUTES) CARD.
C
    READ(5,9)COAD,ALPHA,(ENTRY(J),J=1,12)
9 FORMAT(3A4,F5.0,12I5)
141 DO 10 K=1,10,3
    L=K+1
    M=K+2
C
C CHECK FOR BLANK ENTRIES.
C
    DO 11 N=K,L
    IF(ENTRY(N))10,10,11
11 CONTINUE
    I=ENTRY(K)
    J=ENTRY(L)
C
C CHECK FOR MULTIPLE ITEMS WITH SAME RANK.
C
    IF(ORDER(I))12,12,10
C
C ATTRIBUTE NUMBER STORED IN THE RANK POSITION ELEMENT OF
C THE ORDER ARRAY.
C
12 ORDER(I)=J
    ATTR(J)=ENTRY(M)
    IF(I-RANK)10,10,16
16 RANK=I
10 CONTINUE
C
C READ A REQUEST CHARACTERISTICS (ATTRIBUTES) CARD.

```

```

C      READ(5,13)CODE,(ENTRY(J),J=1,12)
13  FORMAT(3A4,12I5)
      IF(CO这里AD(1).EQ.CODE(1).AND.COAD(2).EQ.CODE(2).AND.
1  COAD(3).EQ.CODE(3))GO TO 141
C
C  CALCULATION OF EXPONENTIAL WEIGHTING FACTORS.
C
      WEIGHT(1)=ALPHA
20  WGT=1-ALPHA
      DO 22 I=2,RANK
22  WEIGHT(I)=ALPHA*WGT**(I-1)
C
C  THIS STATEMENT REPRESENTS THE BEGINNING OF THE LOOP WHICH
C  CONTROLS THE CHECKING OF ALL ENTITY RECORDS.
C
      DO 23 I=1,NA
C
C  THE NEXT SIX STATEMENTS CLEAR STORAGE ARRAYS AND COUNTERS
C
      DO 90 J=1,10
      DO 90 K=1,2
90  BETBAD(J,K)=0
      EXTRA=0
      LESS=0
      SCORE=0.
C
C  THE NEXT FOURTEEN STATEMENTS CHECK TO SEE WHETHER THE
C  ENTITY'S ATTRIBUTES ARE GREATER THAN, LESS THAN, OR EQUAL
C  TO STATED NEEDS. CERTAIN NOT EQUAL ATTRIBUTES ARE
C  RECORDED FOR LATER PRINTING.
C
      DO 224 J=1,RANK
      K=ORDER(J)
      IBEH=STYLE(K)
      GO TO (201,202,203),IBEH
201  IF(CHAR(I,K)-ATTR(K))224,31,224
202  IF(CHAR(I,K)-ATTR(K))24,31,32
203  IF(CHAR(I,K)-ATTR(K))32,31,24
      32 EXTRA=EXTRA+1
      IF(EXTRA.GT.10)GO TO 31
      BETBAD(EXTRA,1)=K
31  SCORE=SCORE+WEIGHT(J)
      GO TO 224
24  LESS=LESS+1
      IF(LESS.GT.10)GO TO 224
      BETBAD(LESS,2)=K
224  CONTINUE
      SCORE=SCORE*100.
      DO 25 II=1,10
      JJ=II
C
C  THIS CHECKS FOR THE PUSHDOWN STORAGE POSITION FOR HOLDING

```

C INFORMATION ON THE CURRENT ENTITY.

C

```

      IF (RESULT(II)-SCORE) 26,25,25
25  CONTINUE
      GO TO 23
26  IF (JJ.GE.10) GO TO 83

```

C

C THE NEXT THIRTY STATEMENTS ARE UTILIZED FOR RECORDING  
C CURRENT ENTITY INFORMATION IN THE PUSHDOWN STORAGE UNITS.

C

```

      JK=9+JJ
      DO 82 II=JJ,9
      MN=JK-II
      LN=MN+1
      IF (LN.GE.11) GO TO 83
      RESULT(LN)=RESULT(MN)
      DO 72 K=1,5
72  TBL(K,LN)=TBL(K,MN)
      DO 93 LL=1,10
      DO 93 K=1,2
93  BSTPOR(LN,LL,K)=BSTPOR(MN,LL,K)
      DO 29 LL=1,4
29  WHO(LN,LL)=WHO(MN,LL)
82  CONTINUE
83  CONTINUE
      RESULT(JJ)=SCORE
      TBL(5,JJ)=EXTRA
      IF (EXTRA.GT.10) EXTRA=10
      TBL(1,JJ)=EXTRA
      TBL(4,JJ)=LESS
      IF (LESS.GT.10) LESS=10
      TBL(2,JJ)=LESS
      TBL(3,JJ)=FILE(I)
      DO 27 LM=1,4
27  WHO(JJ,LM)=LOCA(I,LM)
      DO 91 LM=1,10
      DO 91 K=1,2
91  BSTPOR(JJ,LM,K)=BETBAD(LM,K)
23  CONTINUE
      DO 69 NL=1,7
30  WRITE(6,60) TITLE
60  FORMAT(1H1,'RESULTS OF SEARCH FOR LOCATION FOR ',8A4,
1    '//,49X,'CHARACTERISTICS',/,55X,'VS',/,49X,
2    'SPECIFICATIONS.',/,52X,'NUMBER OF          UP TO TEN ',
3    'SPECIFIC FACTORS WHEREIN')
      WRITE(6,61)
61  FORMAT(1H ,8X,'MATCH',25X,'FILE          INSTANCES WHERE',
1    2X,'ENTITY QUALIFICATIONS',/, ' RANK      VALUE',
2    6X,'LOCATION',10X,'NUMBER          BETTER    POORER',
3    2X,'ARE BETTER',9X,'ARE POORER')
      DO 69 N=1,10
      AA=TBL(3,N)/1000000
      BB=TBL(3,N)/1000

```



```

BB=BB-(AA*1000)
CC=TBL(3,N)-((AA*1000000)+(BB*1000))
MM=TBL(2,N)
MB=MM
NN=TBL(1,N)
NB=NN
IF(NN.LE.0)NN=1
IF(NN.GT.5)NN=5
67 WRITE(1,68)N,RESULT(N),(WHO(N,J),J=1,4),AA,BB,CC,
1 TBL(5,N),TBL(4,N),(BSTPOR(N,J,1),J=1,NN)
68 FORMAT(1H-,I3,F12.5,2X,4A4,2X,I3,'-',I3,'-',I3,
1 4X,I2,7X,I2,3X,5I3)
IF(MM.LE.0)GO TO 691
IF(MM.GT.5)MM=5
WRITE(6,63)(BSTPOR(N,J,2),J=1,MM)
63 FORMAT(1H+,88X,5I3)
691 IF(NB.LT.6)GO TO 692
WRITE(6,650)(BSTPOR(N,J,1),J=6,NB)
650 FORMAT(1H ,70X,5I3)
GO TO 693
692 WRITE(6,651)
651 FORMAT(1H )
693 IF(MB.LT.6)GO TO 69
WRITE(6,652)(BSTPOR(N,J,2),J=6,MB)
652 FORMAT(1H+,89X,5I3)
69 CONTINUE
GO TO 21
999 WRITE(6,96)
96 FORMAT(1H1)
STOP
END

```

## APPENDIX J

### DWELLING SELECTION REQUIREMENTS

## DWELLING REQUIREMENTS

Requestor \_\_\_\_\_

Address \_\_\_\_\_

Telephone \_\_\_\_\_ Date \_\_\_\_\_

Rank*	Characteristics	
_____	1. Maximum monthly payment	_____
_____	2. Minimum size in square feet	_____
_____	3. Minimum number of bathrooms	_____
_____	4. Minimum number of bedrooms	_____
_____	5. Fireplace	Y N
_____	6. Garage	Y N
_____	7. Carport	Y N
_____	8. Number of vehicle spaces	_____
_____	9. Separate dining room	Y N
_____	10. Family room	Y N
_____	11. General dwelling style	_____
_____	12. Central heat	Y N
_____	13. Central air conditioning	Y N
_____	14. Screened porch	Y N
_____	15. Patio	Y N
_____	16. Swimming pool	Y N
_____	17. Wooded lot	Y N
_____	18. Paved drive	Y N
_____	19. Carpeted	Y N
_____	20. Minimum lot size	_____
_____	21. Number of floors	_____

_____	22. Split level	Y N
_____	23. Basement	Y N
_____	24. Maximum distance to grade school	_____
_____	25. Maximum distance to junior high school	_____
_____	26. Maximum distance to high school	_____

**\*Rank:**

Used to indicate the order of importance among the various characteristics of the dwelling. The most important item is to be ranked with a "1". Ranking should continue in a sequential manner through all items.

VITA

Bruce Edgar Herring

Candidate for the Degree of

Doctor of Philosophy

Thesis: NONPARAMETRIC MULTIVARIANT ATTRIBUTE RETRIEVAL  
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